VOLUME XXVIII NUMBER 6 WHOLE NUMBER 234

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY
(Ten numbers per year)

July-August, 1934

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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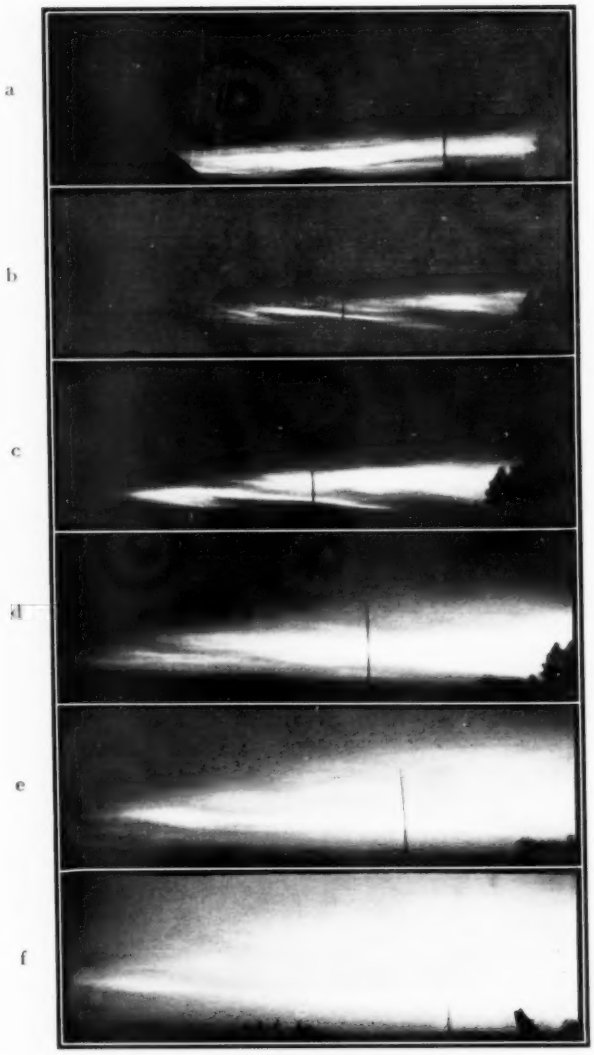
PLATE VI.



PHOTOGRAPHS OF NOCTILUCENT CLOUDS TAKEN AT MEANOOK ON THE NIGHT OF JULY 20-21, 1933.

a. 00.30 (prox.) 105th M.T.; b. 01.39-01.46; c. 01.47-01.58; d. 01.59-02.10; e. 02.11-02.22; f. 02.23-02.34.

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NOCTILUCENT CLOUDS*

By E. H. VESTINE

(*With Plate VI*)

ABSTRACT

The observations and photographs of noctilucent clouds taken at Meanook, Alberta (Lat. 54°37′N., Long. 113°20′W.), on the night of July 20-21, 1933, are given, the observation being possibly the first recorded in America. A method of determining their least possible heights from single station photographs is developed and these heights deduced for the clouds observed at Meanook. A summary of 290 previous observations taken on 187 evenings of the years 1885-1933 is given in brief tabular form. A statistical study of the distribution of evenings of occurrence indicates a close conformity to a normal error law, the maximum frequency appearing about 10 days after the summer solstice, at which time the clouds appear to be most brilliant. The times of yearly preponderance of striking cosmic phenomena, explosive volcanic eruptions and relative sunspots have been compared with the yearly frequencies of noctilucent clouds. The general characteristics of the clouds during the past half century and their probable origin are discussed.

I. INTRODUCTION

NOCTILUCENT, or night-luminous, clouds are of unknown nature and origin and are truly remarkable because of their surprising heights[1, 2] in the stratosphere, and the great velocities[3, 4] they commonly attain. It is generally considered that clouds due to water vapour occur only in the troposphere, of which iridescent clouds ascribed to supercooled water droplets are the highest. The latter type of cloud is common, and is often seen near the sun, giving iridescent effects; but its present wide literature indicates that it is not to be confused with some of the so-called iridescent clouds reported in the journal "Nature" in 1884. Thus very occasionally

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cloud-like formations have been observed in the stratosphere and are of special interest in view of the distribution and importance of water vapour in controlling the temperature of the air.

The lowest clouds in the stratosphere are known as mother of pearl,[5] nacreous or "irisierende Wolken", because of the purity of their beautiful spectral band-like colouration. These occur at heights of 22-30 km. Stenzel[6] and others have observed a peculiar cloud-like phenomenon described as "self-luminous" clouds, the heights of which have not been measured, but which probably also occur at very high altitudes. Although all clouds in the stratosphere are rare in occurrence the most commonly observed are the noctilucent, also called luminous night-clouds or "leuchtende Nachtwolken", which have measured heights of 80-90 km.

Noctilucent clouds are difficult to explain in terms of present conceptions, and observation of them is adding to our knowledge of the upper atmosphere. In our interpretations of air movements in the upper atmosphere we are at present restricted to data derived from the observation of glowing meteoric trains, possibly sunlit aurora[7] and quiet cloud-like remains of aurora, and noctilucent cloud movements within a thin layer, or stratum, at a mean height of 82 km. above the earth. Further developments may result from the fact that the clouds occur near the position of the earth's shadow where peculiar changes also seem indicated from observations on sunlit aurora. Since little is known of this stratum in the stratosphere, noctilucent clouds can furnish valuable information and are of great interest both to the astronomer and the physicist.

Noctilucent clouds have been seen in north temperate latitudes from the latter part of May to the middle of August and in south temperate latitudes during the period of the year about six months later. They are visible only by reflected light from the sun during the time the sun lies from about 10° to 18° below the horizon and usually only under conditions of optimum visibility. Hence they are seen within the twilight circle on summer evenings from points in the zone extending from 45° to 62° north latitudes, according to Jesse, and are brighter in the more northerly latitudes.

In strong displays the clouds may fill most of the twilight circle and have been seen at times as early as 15 minutes after sunset covering the greater part of the sky almost as far as the south-

eastern horizon. As the sun goes lower below the horizon the illumination then recedes symmetrically towards the position of the sun. The clouds continue visible during the night in the portion of the sky restricted to the twilight circle so that the area of illuminated cloud tends to follow the position of the sun, with a minimum extent of display around midnight. A peculiarity some observers have described in the case of brilliant displays is the appearance of what they describe as a zone of darkened appearance in the northwestern sky in the early evening about the time the display is receding through the zenith. Ordinarily the clouds may appear in the northwest about an hour after sunset, the area of illumination progressing with the twilight circle so that illuminated clouds appear in the north and at minimum altitude at midnight. Later they appear mostly in the N. to N.N.E. and appear brighter and the display may fade out in the northwest about an hour before daybreak. Since 1889 the clouds have been seen more frequently after midnight, and observers have rarely seen them higher than 10° above the horizon.

Noctilucent clouds have many remarkable and highly striking characteristics. Ordinarily their form resembles that of cirrus or cirro-stratus, the latter form having been observed more frequently during the early morning hours. They are subject to rapid and continuous change of shape and form, individual details in structure escaping recognition after an interval as short as five minutes. They may appear to twist about, and sometimes take on appearances like that of wound-up lengths of loose yarn. Occasionally they are made up of long parallel silvery streaks aligned along their direction of motion, with smaller parallel streaks at right angles filling the space between and arranged in uniform wave-like sequences. These smaller cloud waves Jesse found at right angles to their direction of motion. They are highly tenuous and the intensity of the light from stars suffers little diminution in passing through them.

The intensity of illumination varies on different occasions. During the summers of 1885 and 1886 they possessed enough brilliance at times to cast definite shadows from terrestrial objects and to permit the reading of ordinary print at night. Ordinarily the

intensity of illumination may be compared to that of the moon near the eastern horizon at the time the sun is just setting in the west.

Their colouring varies with their position relative to the horizon. Near the horizon they have a golden or reddish-orange appearance, and with increasing altitude they take on a white or bluish-white sheen. Still higher they evince a blue-grey hue not unlike that of unpolished silver.

The spectrum shows no emission lines, the Fraunhofer lines being clearly present, and the spectrum on the whole resembling that of daylight.[2] Observers have found the light to be polarized, the only evidence to the contrary being an observation due to Robert von Helmholtz.[8] They are seen clearly through blue filters but the intensity of the light is greatly diminished by red filters.

There is a high degree of consistency in accurate determinations of their heights made in different years and from different locations. Simultaneous photographs of the same clouds against the same background of stars from stations a known distance apart have permitted the identification of the same parts of cloud on each, anp have given accurate determinations of heights. During the summer months of the years 1889-91 Jesse[1] obtained 24 pairs of plates giving 287 heights, ranging from 79 to 90 km., the weighted mean being 82.08 km. In 1932, Störmer,[2] using simultaneous photographs from his auroral stations and applying the same admirable technique he and his colleagues have developed for the determination of the heights of aurora, obtained a mean height of 81.8 km. on July 10, 1932, and 81.1 km. on July 24, 1932, the average mean of 37 heights from 7 pairs of plates being 81.1 km. Measurements have also been made in Moscow, giving a height of 66 km., but the observers question the accuracy of their photographic observations. The use of the earth's shadow method, which can give only an estimate of their least possible heights, has resulted in values of 30-70 km. in Europe. Störmer[2] has shown that this method may give values 30-50 km. too small, owing to the clouds apparently receiving no illumination from the sun's rays passing through the troposphere.

Velocities attained by the clouds are often truly remarkable. Jesse[3,4] obtained a velocity as high as 177 m. per sec. (400 miles per hour) in 1888. Archenhold[4] has published a summary of the results of Jesse's velocity measurements during the years 1889-94. Before

midnight most movements were from an azimuth 48°E., after midnight from azimuth 63°E., with a possible secondary maximum from 73°W. The mean velocity from west azimuths was 31 m. per sec., and 67 m. per sec. from east azimuths. Movements from west azimuths were uncommon and few measurements showed any southern component. Störmer found velocities of 44-55 m. per sec. from the N.N.E. for the clouds of July 10-11, 1932. Thus the clouds appear to move from the N.E. before midnight, from the N.N.E. after midnight and apparently with a component away from the position of the sun or twilight circle.

Jesse obtained measurements varying little from a mean value of 9.4 km. for the distance between successive wave-like crests in the clouds, Störmer[2] finding a value of 9 km. in 1932.

Data on noctilucent clouds were first collected by Jesse in 1885 in a paper "Die Auffallenden Abenderscheinungen am Himmel im Juni und Juli 1885," which gave the observations of some fifteen observers. The first observation in 1885 is due to Backhouse, who observed them at Kissingen on June 8. Rowan, however, states in a paper written in 1886, that he had seen them during the previous two or three years. Earlier observations are probable and Arago[9] has collected a number of observations on various manifestations of luminosity in clouds in a chapter in his works dealing with "l'emission continue de lumière à la surface de certains nuages." He mentions observations on luminosity in clouds made by Rozier on August 15, 1781, by Deluc and Verdeil during 1783, "the year of the great dry dust" and eruption of Asama, and by Beccaris. During 1783 Verdeil mentions a luminosity at night covering the entire sky and permitting the observation of terrestrial objects at a certain distance. Unfortunately, these descriptions are somewhat vague and lacking in detail, particularly with reference to other factors which may have been responsible for the appearance of luminosity.

II. Meanook Observations, July 20-21, 1933.

In the following observations the times indicated are corrected chronometer local zone time (105th M.T.). Angular measurements were made with a pilot-balloon-type theodolite. The azimuth of

the radio pole seen in the pictures in Plate VI was found to be 1.45°W. of N. Photographs *b* to *f* were taken from a fixed position on the flat top of the lookout; *a* was taken from another position. The following is the record of the observations:

23.45—The noctilucent clouds resembled a number of yellowish-orange well-defined cirrus-like streaks about 1° above the horizon in the N.N.W. The streaks were inclined to the horizon at an angle of about 30°, the highest part of each streak being to the west. The streaks were separated by a definite space several times their width. Intensity of illumination 3 (comparing intensity with that of brilliant aurora taken as 4). Gave impression of being at a great distance, and as if illuminated by sun, although sun had set more than an hour previously. No auroral green line (pocket auroral spectroscope used and only a faint general illumination seen through it when directed at the clouds).

24.00—Illumination of the display now extended farther to the east and lower, the streaks in the west having faded out. Fainter and less definite golden and orange fringes and streaks barely visible in north. Gradually the impression that the display was about over was experienced. These streaks and fringes changed in shape, outline and intensity of illumination against their fainter yellowish-orange background so that great difficulty was experienced in attempting to complete a sketch of them. The central position of the area of illumination continued moving east. Plate Ia was taken near the time the display was at a minimum of about 00.30, a long exposure of about 15 minutes being given with a cheap box camera loaded with roll film. After this time the display appeared to brighten somewhat in the N. to N.N.E.

1.10—Estimated range of the cloud display, 5°W. to 25°E.

1.26—Maximum height 1.70° at 6.2°E. Display brightening considerably, especially in western portion.

1.39-1.46—Plate VI*b* exposed.

1.47-1.58—Plate VI*c*.

1.55—Display extending to 20°W.

1.59-2.10—Plate VI*d*.

2.05—Illumination extending westward to 35°W. Highest angular height 3.57°. Colouration white, sharp and beautifully clear.

2.11-2.22—Plate VI*e*.

2.18—Quite bright, more than four on auroral classification. Brightest along lower edge of largest cloud giving a straight white line effect there. No auroral line present.

2.23-2.34—Plate VI*f*.

2.25—West to 36.7° from north.

2.32—A new blue-grey cloud observed at 12.3°E.-32°E. at altitude 9.7°. Resembled a very long lenticular cumulus cloud with lower edge silhouetted like

the lower part of a series of fairly regularly spaced dark smoke puffs partially joined together in line.

2.35—New portion becoming illuminated at 21.5°W. and 7.7° altitude.

2.38—Clouds to the N. and N.N.E. quite faint but to the N.W. still clearly defined against the darker background of the sky. Close to the northern horizon a noticeable orange to reddish glow.

2.52—Purplish hue on clouds 45°W. and 1° altitude and on clouds at 50°W. and 1-2° altitude. Brightness most marked in westward part of twilight circle. Reddish-purple portion in extreme N.W. fading rapidly at 3 a.m. In twilight zone low in N.E. a number of very long (very thin) faintly dark striations running from west to east which were not a part of the display. Steady crackling static very marked on radio. Purple of twilight to about 30° south of zenith.

3.34—Only visible portion a short pair of striations together at 80°W. and 7° altitude. These appeared to shine with a white light although no stars could be seen in that region.

The movement of the clouds was from the E.N.E. The moon was a narrow crescent 24 hours before new. At 24.00 a dull auroral arc consisting of several dull scattered rays was seen several degrees above the display of noctilucent clouds and showed the green auroral line. The aurora lasted about five minutes.

Since there had been no evidence of any thunderstorms in this region the Bureau of Standards in Washington was communicated with to ascertain if anything unusual in the height of the Kennelly-Heaviside layer had been noted which might be associated with the radio static disturbances. Dr. E. C. Crittenden states that unfortunately records for the particular night of July 20-21 were not obtained and kindly comments as follows:

> During most of the year, reflected waves from the upper atmosphere at 2500-4400 kc./sec. at night come most often from the F region, with virtual heights of the order of 300 km. However, it frequently happens that strong reflections will suddenly appear from the E region with virtual heights of the order of 100 to 120 km. These E-region reflections were especially prevalent during June and July. Thus, they were in evidence on 17 of the 20 nights in July for which records were available. They were particularly strong during the night of July 19-20. During six consecutive nights in October, on the other hand, these reflections appeared only once. It is possible that the changes in the E region may be connected with appearances of the noctilucent clouds you mentioned, and it is hoped that further observations will throw more light on this question.

On the night of July 20-21 at sunset, the western sky was cloudless. The visibility increased to 9 during the night. On the fol-

lowing day the sky appeared unusually blue. The barometer had remained very steady but low for several days.

A. Thomson, Chief Physicist of the Meteorological Service of Canada, gives the following summary with respect to weather conditions:

> On the morning of July 20th, a poorly defined front or frontal zone had developed along the Rocky Mountains from Alaska to the International boundary, which divided the Polar Pacific air covering British Columbia from the Polar Canadian air over the western provinces. A large area of moderately high pressure was centered some distance off the British Columbia coast while a low-pressure area covering the provinces of Alberta, Saskatchewan and Manitoba had a centre at 8.00 a.m. about 200 miles west of Port Nelson on Hudson Bay. The pressure gradients were small at the surface so that the winds recorded at all synoptic weather stations in Alberta, Saskatchewan and Manitoba did not exceed 10 miles per hour. The morning temperatures in Alberta were low but rose rapidly.
>
> During the following 24 hours, covering the period noctilucent clouds were observed, the frontal zone became very broad but appeared to have moved eastward. The pressure decreased slightly over Western Canada, and the gradient over the Rocky Mountains became of the order of 1/10 inch for 400 miles. The pilot balloon observations at levels from 1 km. to 4 km. showed moderate westerly or northerly winds so that probably a slight current of Pacific air during the night of July 20-21, was blowing across the Rockies.

The following table summarizes the meteorological data at Meanook for July 20-21:

	July 20, 9h.	July 20, 21h.	July 21, 9h.
Pressure observed (in.)..	27.55	27.57	27.59
Sea level (in.).....	29.94	29.98	29.98
Temperature (°F.).....	52.0	46.4	56.2
Relative humidity.....	73	89	72
Vapour tension (mm.)..	7.2	7.2	8.3

III. Method of Calculation of the Least Possible Heights of Sunlit Clouds at High Altitudes Above the Earth

The problem is essentially that of calculating the height of a sunlit cloud particle lying on the edge of the earth's shadow, being given the time, azimuth and apparent altitude of the particle as observed from a known point on the earth lying within this shadow.

Should the sunlit particle be outside the earth's shadow, a value giving its least possible height can then be deduced.

The plane of the paper (Fig. 1) includes O the centre of the earth, the position F of a sunlit particle of cloud just touched by a ray S from the sun passing at grazing incidence to the earth, E the point of grazing incidence to the earth, and the centre of the sun. Let

A be the position of the observer on the surface of the earth but not necessarily in the plane EFO

AB the tangent plane to the earth at A

D the point on the earth directly beneath the particle

R the radius of the earth adjusted for latitude and sea-level

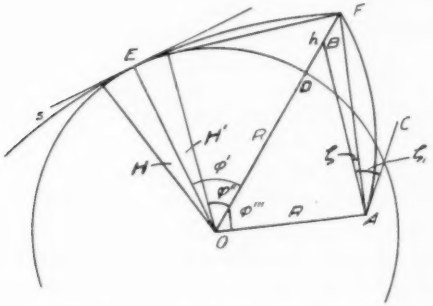

Fig. 1. Position of sunlit particle with reference to a refracted ray s from the sun which passes at grazing incidence to the earth.

h the height of the cloud particle above the earth

H the horizontal astronomical refraction for the ray from the sun grazing at E

H' the horizontal refraction for the ray passing along a length of path EF in the atmosphere

ϕ' the apparent dip of the horizon as seen from F

ϕ'' the dip of the horizon as seen from F corrected for the refraction H'

ϕ''' the angle between radii of the earth at A and D

ζ_1 the apparent angular altitude of the sunlit particle above the tangent plane at A, as observed at A

ζ the apparent angular altitude after being corrected for the atmospheric refraction of the ray passing along the path FA, calculated for the atmospheric conditions approximately known at A

α the azimuth of the particle from the meridian taken positive from north around by east

(L, ϕ) west longitude and latitude of the observer

(L_1, ϕ_1) west longitude and latitude of the point D

h_1 the negative altitude of the sun as seen from D

t_1 hour angle of the sun at D

δ the declination of the sun

s semi-diameter of the sun.

The factor upon which the amount of the atmospheric refraction of a ray depends at a particular height is given by [10]

$$k = 670.4 \frac{p}{T^2} (\tau + 0.0342)$$

where p is the atmospheric pressure

τ the lapse rate in °A/meter

T the absolute temperature.

For altitudes as great as 40 km., k becomes very small, even for large lapse rates, and if calculated is of the order 0.001, so that no significant error in the calculated amount of refraction for rays above this region will result if k be neglected. For altitudes greater than 40 km. the ray of light passing along the path EF may then be treated as subject to horizontal astronomical refraction, and the ray along FA as subject to astronomical refraction.

Then from the figure the dip of the horizon as seen from F is given by $\phi' = \phi'' + H'$ .....(1)

$$\text{also } \sec \phi'' = \frac{R+h}{R} = 1 + \frac{h}{R} \quad \text{.....(2)}$$

An expression for h can be obtained in terms of R, ζ and ϕ''' from

$$\frac{R+h}{\sin (90° + \zeta)} = \frac{R}{\sin (90° - \phi''' - \zeta)}$$

$$\text{or } h = R \left[\frac{\cos \zeta}{\cos(\phi''' + \zeta)} - 1 \right] \text{.....(3)}$$

L_1, ϕ_1 the latitude and longitude of D are given by the formulae

$$\sin (L_1-L)\cos\phi_1 = -\sin\phi'''\sin\alpha$$
$$\sin\phi_1 = \cos\phi'''\sin\phi - \sin\phi'''\cos\phi\cos\alpha.$$

Since ϕ''' is usually small the differential formulae

$$L_1 = L + \frac{\phi'''\sin\alpha}{\cos\phi}, \quad \ldots\ldots (4)$$

$$\phi_1 = \phi - \phi'''\cos\alpha \quad \ldots\ldots (5)$$

may be used.

Then the negative altitude of the sun h_1 as seen from (L_1, ϕ_1) at the time of observation may be computed from

$$\sin h_1 = \sin\phi_1\sin\delta - \cos\phi_1\cos\delta\cos t_1 \quad \ldots\ldots (6)$$

where $t_1 = t+12-L_1/15+E$, t being the Greenwich Civil Time of observation and E the equation of time. The values of δ and E may be taken from tables of the sun's ephemeris.

The negative altitude of the sun in order that F may be just touched by some part of the sun's rays is given by

$$h_1 = \phi' + H + s \quad \ldots\ldots (7)$$

The value of h is then completely determined by means of these 7 equations, and may be solved for in terms of known values. It is found more economical, however, to carry out part of the deduction graphically and approximate the value of h, as follows:

A graph may be constructed from (2) so that h becomes known for a given value of ϕ'' (Fig. 2).

From (3) a series of curves may be drawn for the values of $\zeta = 1°, 2°, \ldots$ or if preferred the values of ζ obtained from the observations, for various values of h and ϕ''', so that for any value of ζ and assumed h, then ϕ''' may be read off (Fig. 3).

The value of ϕ''' thus obtained may be substituted in (4) and (5) so that (L_1, ϕ_1) is obtained for the height assumed and the observed azimuth of the point, and h_1 obtained from (6). If $h_1-(H+H'+s)$ comes out greater than ϕ'' as given in Fig. 2, the height assumed has been too small, and three or four trials will readily approximate the minimum height of the cloud particle in order that it may be just illuminated by some portion of the rays of the sun.

If the height h is less than 40 km. the solution may be carried out in the same manner from the approximate formulae

$$\phi' = \left[\frac{2}{R(1-k)}\right]^{\frac{1}{2}} \sqrt{h}$$

$$\frac{h}{R} = \phi''' \tan \zeta_1 + (\tan^2 \zeta_1 + \overline{1-k} \sec^2 \zeta_1) \frac{\phi'''^2}{2}$$

where the value of k used may be obtained graphically from the relation for k given above, since it depends on the height.

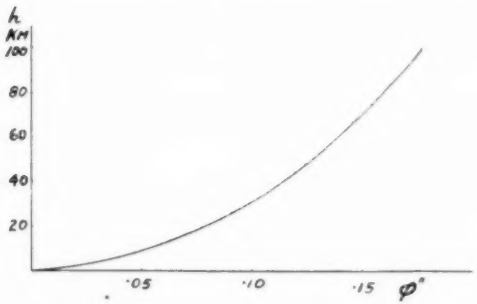

Fig. 2. Value of depression of the horizon ϕ'' in radians as seen from a point at various altitudes in km. above the earth by unrefracted light.

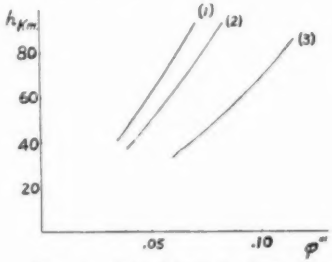

Fig. 3. The altitude in km. of a particle in the atmosphere for a given value in radians of the angle between the radius of the earth at the point of observation, and the line joining center of the earth to the particle, for a given value of the true angular altitude in degrees above the tangent plane at the observer. Curves (1), (2) and (3) refer to values of ζ obtained from ζ_1 given in table of heights.

The following values for the least possible heights were obtained for the clouds observed at Meanook:

G.M.T.	ζ_1	a	L_1	ϕ_1	$h_1 - 2H - s$	h km.
9.05	3.57°	8°W	114°32′	59°33′	0.1261	51
9.27	9.7°	22.0°E	112°19.5′	57°07′	0.1322	57
9.35	7.7°	21.5°W	115°28.5′	57°46′	0.1272	55.5

IV. Summary of the Observations, 1885-1933

In spite of the rarity of the phenomenon a fair amount of observational material has accumulated during the past fifty years. At least 300 observations of varying excellence have been made. The published information, however, is so widely scattered in

various scientific journals covering this period that a brief summary of the main features has been attempted.

Noctilucent clouds were observed frequently during the summer months of 1885-1894. While most marked in their brilliancy and frequency in 1885-1886, from 1888-1894 they fell rapidly in intensity so that only four weak displays are given by Jesse for 1894. In the earlier years it was observed that the clouds were very bright before midnight but in later years they were more intense after midnight. During 1885, however, observations were usually continued only up to the midnight minimum when the clouds disappeared. In 1889-1894, the clouds were observed only six times before but 33 times after midnight. In 1885 the clouds appeared as early as 15 minutes after sunset, some displays covering most of the sky; in later years of this period they rarely appeared before an hour after sunset with elevations usually well under 6° in 1894. Towards the end of the period, according to Jesse, the brightness was most marked in August displays. The displays were observed from between latitudes 45° and 62° N. (with a possible observation at 40°N.) and were seen brighter in the northern sections of this zone.

The period 1894-1898 seems one in which noctilucent clouds were either very weak or infrequent in appearance and there is scanty reference to them in well-known journals. The weakness and infrequency since 1894 and the fresh appearance of several displays during June to August in Russia during 1899 appears in "Gaea".

In "Nature", Backhouse indicates the observation of a bright display at Sunderland on July 8, 1903.

From 1904 to 1905 there appears to be little reference to appearances of the clouds. It is possible, however, that if displays were observed during this period they may have been very weak, or interest in them had flagged so much that observers failed to communicate their observations.

Noctilucent clouds were again seen in 1906, 1908, 1909, 1910, 1911 and 1914.

An observation on luminous clouds was made by Meyer in 1916 which, however, indicates some characteristics not usual in noctilucent clouds. According to Wegener they were also seen in 1917,

and he reports observing them during the summers of 1919 or 1920. Archenhold reports that they were seen in 1918.

No reference was found indicating their observation during the years 1921 to 1931, but they reappeared in 1932 and 1933.

In the following list of observations an attempt has been made to collect the observations recorded in well-known German, English and French scientific journals. This list no doubt lacks completeness, but at any rate should give a fair representation of the frequency and nature of the displays seen from a limited portion of northern Europe, during the years 1885-1933. However, in the sparsely settled regions of northern Europe, Asia and America, covering the major portion of the zone favourable to their observation, it is likely that many occurrences would be unreported.

In the summary local time commencing at midnight is indicated for the hours of observation. In most cases this has been reduced from the hours of observation given for the astronomical day. In a few observations where zone time has been used the standard of time is stated. Where the observer has failed to state the standard of time used it is assumed local time is indicated. When it is definitely indicated in the observation that the phenomenon was observed during the early morning hours the date for the morning is placed after that of the date given. The order observed in the list is the sequence: year, date, place of observation, observer, time, azimuth of the display, angular altitude, direction of movement and comments of the observer.

1885

June 8 Kissingen, BACKHOUSE (Met. Mag., vol. 20, p. 133, 1885), very brilliant cirrus clouds late at night, invisible when sun ceased to shine on them.

June 10 Colouring of upper part a steel blue, then dull green to yellow and orange below and reflecting sunlight.

June 23 Steglitz, JESSE (Met. Zs., Bd. 21, pp. 9-15, 1886), 21.50, 55W.-20E., alt. 20°, dir. N.E. 45, circular forms with striations of silver-white cirrus; lower zone somewhat yellowish, silvery above with bluish upper zone.
Danzig, KAYSER, EGGERT, 21.15, W.-E., alt. 55°, no sunset colours except at base; like bright cirrus.
Swinemünde (WILLERT), 22-24, N.-N.N.E., alt. 40°, bright clouds resembling cirrus.
Kiel, E. LAMP, N.W., strongly lit clouds resembling cirrus.
Wilhelmshavn, BÖRGEN, N, lighted and like cirrus.
Berlin, KÜSTNER, 21, NE, resembling cirrus; wound up forms; white illumination, 21.30, alt. 50°. appeared to withdraw towards the west.

June 24 Kiel, LAMP, KRÜGER, 21-24, NW, silvery cirrus-like clouds.
Hamburg, NEUMEYER, 22-23.30, N,NW- bright cirrus-like clouds.
Berlin, KÜSTNER, 23, N., near northern horizon and like cirrus bands.
Steglitz, JESSE, 22.07, E.N.E., alt. 9°, dir. N.E. 67, not as bright as on June 23.
Wilhelmshavn, ANDRIES, 23, N., silvery white clouds; no aurora; weak magnetic disturbance.
Wilhelmshavn, BÖRGEN, 1 a.m. (night of the 24th), N.W.-N., only within the twilight circle.

June 25 Bülow, KAMMERHERRN, 21.45, N.-E., alt. 10°, like aurora.

June 27 Holstein, J. LAMP, 22.15-24, N., alt. 7°, milk-white with a tinge of green; no magnetic disturbance.

June 30 Holstein, J. LAMP, 23, N-W, alt. 12°.

June 30 Steglitz, JESSE, 21.38, alt. 90°, top fringe through zenith; ordinary cirrus dark and moving south; lit clouds stationary; 22.24, alt. 8.4°, least height 41.8 km.

July 1 Steglitz, JESSE, 22-, bright patch seen near horizon.

July 2 Steglitz, JESSE, 21.30-22, very bright; seen through stratocumulus.

July 6 Steglitz, JESSE, 22.19, ordinary cirrus present was dark; seen by SPRUNG also.
Southampton, LESLIE (Nat., vol. 32, p. 245, 1885), 22-, W.-N., alt. 12° for lower edge; a sea of luminous silvery clouds.
Hamburg, KIESSLING (Met. Zs., Bd. 21, pp. 9-15, 1886), greenish yellow clouds; like cirrus.

July 7-8 Wilhelmshavn, BÖRGEN, 22-23, N., only inside twilight circle; unlit portions projecting outside.
Hamburg, MEYER, 21.30, W.-E., alt. 90°, white colouration of cirrus. Seen also by SPRUNG in Germany, and KIESSLING.
Steglitz, JESSE, 20.40, N., dir. N.N.E. 22, clear sky at time of setting of sun at 20.20; 20.53, almost over entire sky; 21.02, very bright; 21.33, alt. 90°, no clouds left in the S.E. sky; 21.53, alt. 24.5°; 22.20, alt. 9.5°; least heights 45 to 56 km.
Berlin, BATTERMAN (Met. Zs., Bd. 21, p. 179, 1886), 1 a.m., N.N.E., cast definite shadows from terrestrial objects; very good visibility; no moon; 1.30 a.m. alt. 8°, 1.45 a.m., N.E., higher and brighter in the sky; 2.05 a.m., N.E., parallel bands present; 2.12 a.m., to Alpha Auriga, stars visible through the clouds; 2.29 a.m., alt. 90°, nearly to zenith, weaker; 2.45 a.m., S.W., dir. N.E.(?), weak in N.E.; 3.10 a.m., almost indiscernible in the N.E.
Rügen, FÜRSTENAU (Met. Zs., Bd. 21, p. 14, 1886), 22.15-24, N., alt. to 30°, shadows cast from terrestrial objects; stars visible through the clouds; followed progress of sun; black threatening zone within twilight circle; seen for 14 days.
Kissingen, BACKHOUSE (Met. Mag., vol. 20, p. 133, 1885).

July 8 Steglitz, JESSE (Met. Zs., Bd. 21, p. 15, 1886), 22-, weak.
July 9 Steglitz, JESSE; seen through ordinary clouds; weak.
July 17 Steglitz, JESSE, 22.02, alt. to 9.8°, somewhat noticeable; 22.08, alt. 9.0°.
Hamburg, KIESSLING, 22.25, N., greenish-yellow cirrus-like clouds.
July 19 Steglitz, JESSE (Met. Zs., Bd. 21, p. 16, 67, 1886, Weltall, 27 Jahrgang, Juli 1928), 20.24, extraordinarily brilliant display commencement; 20.40, alt. 14.3° in S.E.; 21.17, alt. 90°, 22.10, alt. 7.2° in N.W.; appeared 15 minutes after sunset with grey cirrus-like streaks almost over the entire sky excepting a small portion in the south-east. The arrangement of the clouds was extremely regular and consisted of long parallel silvery streaks running from the N.N.E. to S.S.W. separated at the zenith by 10° (12° given in Weltall) and converging towards the horizon like the ribs of a fan. Between these streaks were uniformly spaced cross-ribs at right angles separated at the zenith by about 5°. The display lacked sharp definition at first, became brighter and then dissipated itself progressively from the S.E. to the N.W. About the time that the display extended to the zenith the north-western portion had a dark threatening appearance, while the clouds increased in brilliancy to the time when the clouds were at an altitude of 15° in the N.W. The colouration was reddish-yellow near the horizon in the west, bluish above and finally a duller bluish-white. Direction of movement from the N.N.E. 30 at 20.51, least heights 10-60 km.
Hamburg, SPRUNG, 20.45, over entire sky; 21.45, like polar bands; dir. N.E. 45.
July 21 Breslau, GALLE, 21.30, N.W., alt. 10°, sunset at 20.01; golden yellow near horizon; no magnetic disturbance.
Steglitz, JESSE, 22, N.N.E., alt. 15°, dir. N.W.-22, only a few bright streaks and direction of movement uncertain.
July 22 Steglitz, JESSE, 21.11, alt. 69° S.E., 21.51 alt. 9.2° N.W.; sunset at 20.05, illumination began at 20.40; 20.47, dir. E. 90; least heights 44-55 km.
July 23 Breslau, GALLE, 20.45, alt. 60°, sunset at 19.58; only a small part left at 21.55, colouration a bright white, phosphorescent? Least heights 41-58 km.
July 27 Görlitz, KÜSTNER.
Görlitz, BUSCH (Weltall, 1928), 20.45, dir. E. 90.
July 29 Jönköping (Nat., vol. 32, p. 375, 1885), midnight, bluish clouds like icebergs.

1886

May 28 Isle of Wight (BACKHOUSE), (Nat., vol. 34, p. 239, 1886).
June 2 Sunderland, DIXON.
June 3 Sunderland, DIXON.
June 5 Wilhelmshavn, ANDRIES (Weltall, 1928), 23.
June 8 Hamburg, HANN (Met. Zs., Bd. 21, p. 323, 1886), alt. 20°, in direction towards position of sun.
Steglitz, JESSE (Weltall, 1928), 21, dir. W.N.W. 67.
Rügen, GALLE, 22.

June 10 Steglitz, JESSE,
June 13 Steglitz, JESSE, dir. W.N.W. 67.
Sunderland, DIXON (Nat., vol. 34, p. 239, 1886).
June 16 Sunderland, DIXON.
June 18 Belfast, SHAW (Nat., vol. 42, p. 246, 1890), midnight, N.W., alt. 20°.
June 22 Sunderland, DIXON (Nat., vol. 34, p. 239, 1886).
Dublin, ROWAN (Nat., vol. 34, p. 192, 1886), N., alt. 5°-10°, showed an opaque pearly lustre; says he has seen them during the previous two or three years; azimuthal width 7°.
June 23 Bideford (Nat., vol. 34, p. 239, 1886), upper edge five-eighths of the distance up to γ Andromeda at 22.18.
Sunderland, DIXON, very striking.
Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889).
Hamburg, KÖPPEN (Weltall, 1928), 23.15, stationary.
Hamburg, HANN (Met. Zs., Bd. 21, p. 323, 1886), 23.20, alt. 6°.
June 24 Steglitz, JESSE, 22, dir. E.N.E. 67.
June 26 Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889).
June 28-29 Hamburg, HANN (Met. Zs., Bd. 21, p. 323, 1886), 23.30-01.00 a.m., alt. 4°, height over 50 km.
June 30 Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889).
July 1 Sunderland, BACKHOUSE (Nat., vol. 34, p. 312, 1886).
3 Steglitz, JESSE (Weltall. 1928), 21, dir. N.N.E. 22.
7 Steglitz, JESSE, 22, dir. W. 90.
July 8-9 Dublin, ROWAN (Nat., vol. 34, p. 264, 1886), 23.30-2.00 a.m., 10 W.-30 E., made sketches by cloudlight.
July 9-10 Dublin, ROWAN, 1.30 a.m., N.-N.E., a golden lustre shown at midnight.
July 9 Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889).
July 11 Naugard, KLOPSCH, 21.30, dir. S.W. 135, 22, dir. W.S.W. 112.
July 11-12 Eckerberg, STEINBRINK, 2.30 a.m.
July 12 Southampton, LESLIE (Nat., vol. 34, p. 264, 1886), 19.30-22, N.W., dir. N., cloud waves present; seen previously during the summer; brilliant.
Sunderland, BACKHOUSE (Nat., vol. 34, p. 312, 1886), 22.14 G.M.T., dir. N. -3.
Trier, ANDRIES (Weltall, 1928), 21.15.
July 18 Sunderland, BACKHOUSE (Nat., vol. 34, p. 312, 1886).
July 18-19 Eckerberg, STEINBRINK (Weltall, 1928), 3 a.m.
20 Sunderland, BACKHOUSE (Nat., vol. 34, p. 312, 1886), 21.22, dir. N. or E. covering most of sky (note other article dealing with remarkable halos).
Hamburg, KÖPPEN (Weltall, 1928), 21.30.
July 24 Sunderland, BACKHOUSE, 21.56 G.M.T., dir. E. 90.
July 25 Swinem, KLOPSCH, 21.00, dir. N.W. 45.
Lichtenw, RICHTER, 21.00, dir. N.W. 45.
July 27 Gilsland, BACKHOUSE.
July 27-28 Edinburgh, SMYTH (Nat., vol. 34, p. 312, 1886), 1 a.m., trace of auroral line? Black zone effect above.

July 29 Eckerberg, STEINBRINK (Weltall, 1928), 21.
July 30 Eckerberg, STEINBRINK, 21.30.
Aug. 1 Sunderland, BACKHOUSE, 22.00 G.M.T., dir. E.N.E. 68.
Aug. 10-11 Sunderland, BACKHOUSE (Nat., vol. 34, p. 386, 1886, Weltall, 1928), 2.30-4.11 a.m.; at 3.34 a.m., G.M.T., dir. E. 81; no auroral line; disappearance due to overpowering light of sun in morning.

1887

June 4-5 Steglitz, JESSE (Weltall, 1928), 21.15; 2.30 a.m. dir. E.S.E. 112.
June 6 Berlin, JESSE (Met. Zs., Bd. 24, p. 186, 1889), 21.55, photograph reproduced.
June 9 Königsberg, HAHN (Metz. Zs., Bd. 24, p. 187, 1889), trace.
June 13 Ben Nevis, OMOND (Nat., vol. 38, p. 220, 1888), midnight, seen almost every clear night.
June 14 Clifton, BURDER (Nat., vol. 41, p. 198, 1890), N.N.W., 22.45.
Sark, BACKHOUSE (Nat., vol. 36, p. 269, 1887), weak.
June 15 Königsberg, HAHN (Met., Zs., Bd. 24, p. 186, 1889), quite noticeable; sun ring in afternoon.
June 16 Hamburg, HANN (Met. Zs., Bd. 22, p. 335, 1887).
Steglitz, JESSE (Weltall, 1928), dir. E. 90.
June 17-18 Hamburg, HANN, 2 a.m.
June 18 Hamburg, HANN.
Sark, BACKHOUSE (Nat., vol. 36, p. 269, 1887), weak.
June 19 Königsberg, HAHN (Met. Zs., Bd. 24, p. 186, 1889), 23, over whole northern sky; tolerably bright.
Dublin, ROWAN (Nat., vol. 36, p. 245, 1887), 25W.-50 E., increasing development of phenomena to June 29.
Sark, BACKHOUSE (Nat., vol. 36, p. 269, 1887), weak.
Hamburg, HANN (Met. Zs., Bd. 22, p. 335, 1887).
Steglitz, JESSE (Weltall, 1928), dir. N.E. 45.
June 20 Hamburg, HANN (Met. Zs., Bd. 22, p. 335, 1887).
June 21 Dublin, ROWAN (Nat., vol. 36, p. 245, 1887).
June 23 Königsberg, HAHN (Met. Zs., Bd. 24, p. 186, 1889), trace.
June 24 Königsberg, HAHN, trace.
Dublin, ROWAN (Nat., vol. 36, p. 245, 1887), more developed than on June 21.
June 25 Königsberg, HAHN (Met. Zs., Bd. 24, p. 186, 1889), -24-. Peculiar in that the brownish gold edge appeared before the clouds themselves; fairly strong.
Steglitz, JESSE (Weltall, 1928), 21.00, dir. N. 0.
June 26 Steglitz, JESSE, 21.30, dir. N.E. 45.
Königsberg, HAHN, -24-, glistening towards midnight; sky beneath a dark yellow and "black space" in sky above present as illusion.
Dublin, ROWAN (Nat., vol. 36, p. 245, 1887), more developed than on June 24.
June 27 Königsberg, HAHN (Met. Zs., Bd., 24, p. 186, 1889), weaker; strong sun ring towards evening.

June 27-28 Berlin, HELMHOLTZ (Mets. Z,. Bd. 22, p. 335, 1887), N., alt. 5°, seen all night and a minimum at midnight; spectroscope showed a deficiency of red light in the cloud illumination; light not polarized; blue filters had little effect but red filters greatly diminished the intensity of the light, least height 75 km.

June 28 Königsberg, HAHN, 23.15, present but far away.
Dublin, ROWAN, a magnificent display.

June 29 Dublin, ROWAN, brightest of Dublin displays.
Königsberg, HAHN, sun rings from 8-15 hrs.; a weak display.
Steglitz, JESSE (Weltall, 1928), 21.15, dir. N.E. 45.
Templehof, ETZOLD, 21.30, dir. E. 90.

July 1 Königsberg, HAHN (Met. Zs., Bd. 24, p. 186, 1889), weak trace.

2 Steglitz, JESSE (Weltall, 1928), 21.30, velocity too low to be measurable.

July 3 Steglitz, JESSE, 21.30, dir. W. 90.
Stettin, KLOPSCH, 21.30, dir. N.N.W. 22.
Königsberg, HAHN, shifting from N.W. to N.E. noticeable; distinct.

July 4 Königsberg, HAHN, very weak.

July 6 Königsberg, HAHN, tolerably strong.
Chamonix, BACKHOUSE (Nat., vol. 36, p. 269, 1887), brilliant display.
Steglitz, JESSE (Met., Zs., Bd. 22, p. 424, 1887), height from simultaneous photographs gave 75 km., uncertain.

July 7 Karlsruhe, V. REBEUR PASCHWITZ (Weltall, 1928), 21.15.

July 9 Königsberg, HAHN, 22, not present at 21 hrs.; partly like white fog, higher up like granulated snow.

July 14 Königsberg, HAHN, weak.

July 15 Königsberg, HAHN, weaker than on 14th.

July 17 Königsberg, HAHN, weak, but traces near horizon.

July 18 " " " " " " "

July 19 " " " " " " "

July 20 Ben Nevis, OMOND (Nat., vol. 38, p. 220, 1888).

July 22 Königsberg, HAHN (Met. Zs., Bd. 24, p. 184, 1889), doubtful trace.

July 24 Königsberg, HAHN, as on July 17-19.

July 25 " " " " "

July 29-30 Sunderland, BACKHOUSE (Nat., vol. 36, p. 365, 1887, Weltall, 1928), 22.52 N.N.W.-N.N.E., dir. N.E. 45, seen mostly in the morning; very brilliant; a border of faint yellow above the blue colouration; present also at 2.26 a.m., G.M.T., dir. N.N.W. 34.

July 30 Königsberg, HAHN (Met. Zs., Bd. 24, p. 184, 1889), at 22.30 only one small patch; distinct.

July 31 Königsberg, HAHN, very weak, none in August. Seen on 25 out of 45 clear nights of the summer of 1887.

1888

June 3 Königsberg, HAHN, aurora?

June 4 Ben Nevis, OMOND (Nat., vol. 38, p. 220, 1888), midnight, visible almost every clear night up to July 2.

June 12 Cornwall, BACKHOUSE (Nat., vol. 38, p. 197, 1888), faint.

June 14 Cornwall, BACKHOUSE, weak; growing fainter each summer since 1885.

June 22 Steglitz, JESSE (Met. Zs., Bd. 25, p. 369, 1888), now appearing 1¼ hours after sunset.

June 23 Steglitz, JESSE.
Stolp, V. REBEUR-PASCHWITZ (Met. Zs., Bd. 23, p. 369, 1888).
Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889), seen widespread over Europe, at least 7 different localities; brownish-gold at horizon.
Moscow, CERASKI (Met. Zs., Bd. 23, p. 369, 1888).

June 24 Königsberg, HAHN, stronger than on June 23. Also seen at Steglitz and Hamburg.

June 25 Königsberg, HAHN, clearly present. Also seen at Steglitz and Hamburg.
Sunderland, BACKHOUSE (Nat., vol. 38, p. 197, 1888), first very distinct display of the year.

June 26 Königsberg, HAHN, "black space" above.

July 1 Sunderland, BACKHOUSE (Weltall, 1928), 22.45, G.M.T., N.N.W. 67.

July 4 Königsberg, HAHN, through clouds.

July 4-5 Steglitz, JESSE.

July 5 Königsberg, HAHN, through clouds.

July 7 Königsberg, HAHN, weak; sun ring in afternoon.

July 15 Königsberg, HAHN, trace.

July 23 Königsberg, HAHN, trace deep on horizon; none in August.

Dec. — Puntas Arenas, STUBENRAUCH (Met. Zs., Bd. 24, p. 186, 1889), seen twice during the southern summer.
Beagle Channel (Astr. Nachr. No. 2885), seen several years ago. HAHN observed the clouds on 10 out of 31 clear nights in 1888.

1889

June 7 Dublin, ROWAN (Nat., vol. 40, p. 151, 1889), 22-24.

June 12 Steglitz, JESSE (Nat., vol. 43, p. 60, 1890), height 90 km.

June 22-23 Steglitz, JESSE (Astr. Nachr. Bd. 140, p. 161, 1896, long table of heights given for the years 1889-1891 determined by several station simultaneous photographs; range of mean heights 81-89 km., mean 82.08±0.009 km.), 13.53 (B.M.T).

July 2-3 Steglitz, JESSE (Sitzber. Ak. Wiss., Berlin, p. 1031, 1890-91; Met. Zs., Bd. 25, p. 37, 1890; Weltall, 1928), 1.21-2.06 a.m.; dir. E.N.E. 68, velocities 94-177 meters/sec.

July 9-10 Steglitz, JESSE, 1.51 a.m., alt. 6.6°, dir. W.S.W. 106, velocity 57 m/sec.

July 24-25 Steglitz, JESSE, 2.47 a.m.

July 30 Copenhagen, PECHÜLE (Astr. Nachr., Bd. 126, Nr. 3002, p. 29, 1891). Midnight, band up to only ¾° above horizon in north; a higher cloud in N.E.; one hour later, 5 E.-45 E., alt. 3°.

July 31-1 Steglitz, JESSE, 2.48 a.m.

Aug. 11 Lat. 48.5°N., Long. 34.4° W., VOGELSANG (Met. Zs., p. 440, 1889).

Aug. 18-19 JESSE (Met. Zs., Bd. 25, p. 38, 1890), seen in morning.
Lillelevdalen, STÖRMER (University Observ., Oslo, Pub. 6, p. 44, 1933).

1890

May 26 Steglitz, JESSE.

June 17-18 Sussex, M. E. (Nat., vol. 42, p. 198, 1890), 22.30-1 a.m., quite bright; purplish haze above, then white and finally yellow below.

June 17 Kingstown, ROWAN (Nat., vol. 42, p. 222, 1890), first conspicuous display of the summer.
Sunderland (BACKHOUSE), (Nat., vol. 42, p. 246, 1890).

June 25 Kingstown, ROWAN (Nat., vol. 42, p. 222, 1890), luminous forms now less definite and more nebulous than in former years.

June 29 Ben Nevis (ROWAN).

July 4 Aberdeen, ROWAN, alt. 30°, ending above in cirrus-like wisps.
Belfast, SHAW (Nat. vol. 42, p. 246, 1890), 22-, N.-N.E., alt. 15°, very storm-tossed, like scattered cirrus after a storm.

July 6-7 Urania, ARCHENHOLD (Weltall, 1928), 1.41 a.m., alt. 14°, dir. E.S.E. 114, mean velocity 46 m./sec.; 2.23 a.m., alt. 15°, dir. E.N.E. 64, velocity 79 m./sec.; 2.28 a.m., alt. 15°, dir. N.E. 54, velocity 84 m./sec.

July 9-10 1.29 a.m., alt. 15°, dir. N.N.E. 19, velocity 55 m./sec.

July 10-11 1.17 a.m., alt. 14°, dir. N.E. 46, velocity 71 m./sec., also seen at 22.34.
2.11 a.m., alt. 16°, dir. N.E. 60, velocity 40 m./sec.
2.29 a.m., alt. 24°, dir. E.N.E. 85, velocity 83 m./sec.

July 12-13 Copenhagen, PECHÜLE (Astr. Nachr. B. 136, p. 319, 1894), -24-, 60 W.-60 E., alt. 5°.

July 15-16 Sunderland, BACKHOUSE (Weltall, 1928), 2.36 a.m., G.M.T., alt. 24°, dir. N.W. 1, velocity 151 m./sec.

July 24-25 Steglitz, JESSE (Astr. Nachr., Bd. 140, p. 161, 1896), 2.22 a.m.

Oct. 27 Grahamstown (Astr. Nachr., Bd. 126, Nr. 3008, p. 123, Met. Zs., Bd. 27, p. 231, 1892), 19.45-20.32, in latitude 30°S. (Authenticity a matter of opinion).

1891

June 3 Kingstown, ROWAN, (Nat., vol. 44, p. 231, 1891).
June 7 " "
June 9 " "

June 25-26 Steglitz, JESSE, 1.24-2.10 a.m. (Astr. Nachr., Bd. 140, p. 161, 1896).

June 30 Sunderland, BACKHOUSE, dir. N.E.
Kingstown, 23.30-00.30 a.m., alt. 5°.

July 10-11 Copenhagen, PECHÜLE, trace early in evening.

July 11-12 Copenhagen, PECHÜLE (Astr. Nachr. Bd. 136, p. 319, 1894), -24-, 25 W.-25 E., alt. 1°, bright.

1892

May 17 Haverford (Met. Zs., Bd. 27, p. 414, 1892), in lat. 40°N. (according to a letter to Jesse).

July 24 Butterworth, LEY (Nat., vol. 46, p. 294, 1892), 21.35-22.35.

July 24-25 Ben Nevis (LEY).

July 24-25 Copenhagen, PECHÜLE (Astr. Nachr. Bd. 136, p. 319, 1894), 2 a.m., 30 W.-60 E., alt. 10°, brightest at 25°W.
Seen 10 times in 1892 and brightest Aug. 2-6 (Jesse).

1893

June 15 Kiel, LAMP (Astr. Nachr. Bd. 133, p. 131, 1893), 23 hrs.
16 Kiel, LAMP, 23 hrs.

July 8 Kiel, KREUGER.
Steglitz, JESSE, 22.30 N.W.

July 8-9 Copenhagen, PECHÜLE (Astr. Nachr. B. 136, p. 319, 1894), 23 hrs., at 24 hrs., 40 W.-15 E., alt. 7°, brightest at 10°W.; 1 a.m., 50 W.-0, alt. 15°, brightest at 25 W., white clouds at alt. 5°, and blue at alt. 15°.

1894

June 9-10 Copenhagen, PECHÜLE, -24, 40 W.-15 W., alt. 2°, a minimum at midnight and clouds at 00.30 at 35 W. and 1.5° alt.

July 12-13 Grunewald, ARCHENHOLD (Weltall, 1928), 1.59 a.m., alt. 14°, dir. E.S.E. 106, velocity 47 m./sec.
Four weak appearances in 1894 (JESSE).

1899

June 28 Linz, BAUERNBERGER (Met. Zs., Bd. 35, p. 419, 1900), 23 hrs., N.W., doubtful display.

June to
August Russia, HANN, (Met. Zs., Bd. 35, p. 182, 1900; Gaea, vol. 35, p. 634, 1889), fresh recurrence of several displays; brightest in the N.E. after midnight; seen weaker and infrequently during recent years.

1903

July 8 Sunderland, BACKHOUSE (Nat., vol. 59, p. 31, 1903), bright display; volcanic dust corona about sun all day.

1906

July 19 Sunderland?, BACKHOUSE (Nat., vol. 78, p. 127, 1908).

1908

May 27 Sunderland, BACKHOUSE (Nat., vol. 78, p. 127, 1908), a very feeble display.

June 29 Bristol, DENNING (Nat., vol. 78, p. 247, 1908), nights preceding June 29 unusually dark.
Russia, SHOENROCK, (Met. Zs., Bd. 43, p. 369, 1908), two observers state display seen on this date.

June 30-1 Russia, SHOENROCK, very brilliant and many observers; display seen in latitudes 45°-60°N., east longitudes 23°-48° for the displays of June 29-July 2. Most observers saw the display of June 30 in the north in some cases nearly to the zenith; colouration orange or reddish-orange or greenish; velocity 83 m./sec. from the east.[24]
Heidelberg, WOLF (Met. Zs., Bd. 43, p. 556, 1908), -24-, N., alt. 49°, dir. E., brightness of day at 1.15 a.m., due to lit cirrus-like clouds; thought the display due to a sinking cloud of dust; colouration brownish.

June 30-1 Berlin, GELLHORN (Met. Zs., Bd. 43, p. 365, 1908), positive identification not assumed, 22 hrs., greenish to bright blue above, then yellowish-red and finally brownish-red near the horizon.

Arnsberg, BUSCH (Met. Zs., Bd. 43, p. 314, 1908), 22.55, alt. 5°, entire twilight zone filled with noctilucent clouds; least possible height 52 km.; Bishop's rings the following day; exactly similar to the noctilucent clouds of 1885.

Krakau, KRASSOWSKI (Met. Zs., Bd. 43, p. 313, 1908), 22 hrs., (M.E.Z.) N.W.-N., bright with dirty yellow colouration; 23.15, alt. 90°, very bright and illuminating distant terrestrial objects.

Prague, BRAUNER (Nat., vol. 78, p. 221, 1908), 23-1.30 a.m. N.N.E.-N.E. alt. 20°-30°, orange to yellow colouration.

Bristol, DENNING, very strong glow over the north at midnight.

July 1 Russia, SHOENROCK, much weaker.

Berlin, GELLHORN, 22-24, much weaker.

Heidelberg, WOLF, dir. E., much weaker.

Arnsberg, BUSCH, light strongly polarized negatively.

Bristol, DENNING, many clouds of various tints at night; brilliant.

July 2 Bristol, DENNING, N., attractive coloured cloud scenery; weaker.

Berlin, GELLHORN, much weaker than on July 30.

Russia (SHOENROCK), weak.

1909

July 27-28 Dröbak, STÖRMER,[2] 23.

1910

June 24-25 Seebad Bansin, ARCHENHOLD (Astr. Nachr., Bd. 185, p. 87, 1910; Weltall, 1928), 22.30-1.30 a.m.

July 17 Wongrowitz, KORN (Weltall, 1928).

Berlin?, ARCHENHOLD, 22.05-22.35 (Weltall, 1928), alt. above Capella. Seen after a wonderful red sunset.

1911

June 24 Bothkamp, SCHILLER (Astr. Nachr., Bd. 189, p. 71, 1911), seen on the nights of June 24 to July 9.

July 4-5 Heidelberg, WOLF (Astr. Nachr., Bd. 189, p. 15, 1911), 1.25 a.m., M.E.Z., 0N-8 E., alt. 6°, colouration from above to horizon was first bluish, then greenish, yellow ochre, brownish red and finally blood red at horizon the entire night.

July 11 Königsberg, BATTERMAN (Astr. Nachr., Bd. 189, p. 71; Met. Zs., Bd. 46, p. 416, 1911), 1.04 a.m., alt. 5°; like the clouds of 1885. Seen especially after midnight on the nights of July 11, 13, 14 and 15.

1914

June 27 Königsberg, BATTERMAN (Met. Zs., 1914), 22.45 L.M.T., N.N.W.-N.E., alt. 10°; -24-, alt. 5°.

July 1 Königsberg, BATTERMAN, -24-.

July 5 Königsberg, BATTERMAN, -24-.

1916

Aug. 25 Steckborn, MEYER (Met. Zs. Bd. 51, p. 517, 1916), 23.28, concavity of bands towards east.

1917-1918 (GUTENBERG,[16] ARCHENHOLD[4]).

1919 or 1920 (WEGENER, Met. Zs., Bd. 63, p. 404, 1925.)

1919, 1920 (GUTENBERG[16]).

1920

June 29-30 Germany, BOTTLINGER (Met. Zs., Bd. 55, p. 230, 1920), 1.30 a.m., N., alt. 6°-7°; 2 a.m., N., alt. 20°, dir. N.E. or N.N.E.; end of display at 2.50.

1932

July 1-2 Riga, MEYER, 00.20 E.E.T., alt. 25°44′ in N.N.W., least possible heights 51.7-55.3 km., colouration bright greenish-blue with yellow twilight horizon.[2]

July 7-8 Hanover, HARTMANN (Met. Zs., Bd. 49, p. 272, 1933), 1.45 a.m., alt. 30°, dir. N.N.E., glistening white cloud; 2.15 a.m., alt. 50°, dir. N.N.E., velocity 22 m./sec.; least possible height 25 km.

July 10-11 Oslo, STÖRMER, mean height 81.8 km. with range in values 74-92 km.; velocities 44-55 m./sec.[2]

July 13-14 Bergen, BJERKNES, 22-1.14, G.M.T., N.W.-N.E., alt. 10°, dir. E., velocity 90 m./sec. if height taken as 80 km.; colouration bluish-white and more greenish-white at the western and eastern ends; like ci. filosus and cicu. undulatus in mixed composition.[2]
Mehammersåta on Stord, Jelstrup, midnight, dir. N.E.; at 1.06 M.E.T. the clouds had moved far to the S.W.[2]

July 23-24 Darbu, HASSEL, 00.45 M.E.T., small faintly luminous cirrus-like clouds in N[2].

July 24-25 Oslo, STÖRMER, appeared some time after sunset and faded out in the dawn; mean height 81.1 km., range in values 75-85 km., dimensions of cloud waves 9 km.[2]
Darbu, HASSEL, brighter than on July 23-24.[2]

Aug. 8-9 Sollia (about 62°N. lat.), WISCHMANN, 1 hr. E.M.T., N.N.W., alt. 5°-10°, dir. E.; when first seen were feebly bluish-white, yellow later, and almost white when they disappeared at 3.30.

1933

July 12-13 Köln, MALSCH (Zs. f. ang. Met., H.8, 50 Jahrg., p. 255, 1933), 2.30 a.m. M.E.T., no stars could be seen; 2.45 a.m., N.W.-N.E., alt. 15°; least possible height 64 km., dir. N.E.-E., velocity greater than 80 m./sec.

Aug. 6 Ostseebad, SPANGENBERG, idem, p. 324, 22.10, N., alt. 34°, dir. W., greenish-blue colouration, more whitish later; moved 76° in 20 minutes,

Sept. Ostseebad, SPANGENBERG, 22.15, alt. 12.5°, colouration greenish.(?)

(To be contined)

TWO GREAT ASTRONOMERS—TYCHO BRAHE AND JOHN KEPLER*

By Charles Hartley

TO estimate the services rendered to astronomy by Tycho Brahe and John Kepler, it is necessary to give a short account of the discoveries made and the theories promulgated before their advent.

For thousands of years before Christ the heavenly bodies had been observed and their motions studied by the civilized and even uncivilized nations of antiquity; and records had been collected by Chaldeans, Egyptians, Hindus, Chinese and Arabians: but it is to Greek philosophers that we owe the first tolerably correct views of their structure and movements. Thales of Miletus about 600 B.C. foretold an eclipse and pronounced the earth to be a sphere. Pythagorus and Nicetas of Syracuse are said to have taught that the earth revolves round the sun. Hipparchus of Rhodes about 160 B.C. verified Eratosthenes' discovery of the eccentricity of the sun's apparent orbit, measured the year correctly within twelve seconds and revealed the precession of the equinoxes. Three hundred years later Ptolemy of Alexandria, besides contributing observations of his own, reduced those of Hipparchus and other astronomers to a complete system called the Ptolemaic, according to which the earth was the centre of the universe, and the sun, moon, planets and stars revolved round it in separate hollow spheres. This theory remained unchallenged until the publication of Copernicus' book, "On the Revolutions of the Celestial Orbs", in A.D. 1543. During these fourteen centuries the minds of the learned, and especially of the clergy, were dominated by the authority of Ptolemy, so that it became heretical to question it. Even Alfonso the Wise, King of Castile, in the thirteenth century was regarded with suspicion owing to his remark that "it was a crank machine; and the Almighty should have taken advice".

The fifteenth and sixteenth centuries witnessed an immense out-

*An address to the Victoria Centre of the Royal Astronomical Society of Canada, October 6, 1933.

burst of intellectual activity manifesting itself in every field of thought and signalized by four heroic names in astronomy, Copernicus, A.D. 1473 to 1543, Tycho Brahe, 1546 to 1601, Galileo, 1564 to 1642, and Kepler, 1571 to 1630.

Tycho Brahe, although he rejected Copernicus' theory, yet by his painstaking and conscientious observations enabled Kepler to confirm it in its chief aspects. The eldest son of a nobleman in the royal service, he was born in southern Sweden, then dependent on Denmark. He was adopted by a wealthy uncle and educated in law at Copenhagen and Leipzig, but devoted himself from an early date to astronomy, his imagination being fired by an eclipse of the sun in August, 1560. His privatte life was picturesque beyond that of most scientists. To fellow astronomers he was generous and considerate, especially to Kepler, who greatly needed assistance: to equals and superiors he was overbearing and truculent; so that in his student days he engaged in a duel with a Swedish nobleman to be fought with swords in the dark, whereby he lost his nose, which he replaced with an artificial one. He was so deeply conscious of his rank, that having composed a small book on a new star in Cassiopeia, he was with difficulty persuaded to publish it, owing to aristocratic prejudice, which he soon after defied by marrying a peasant girl. The merit of this little work lies in his insistence on the enormous distance of the conflagration. As he was contemplating settling in Germany, he was persuaded by his sovereign, King Frederick II, to accept the island of Hveen in the Sound and a sufficient income to carry on his researches. Here he spent his large fortune on astronomical apparatus, buildings and workshops, correcting and enlarging the observations of earlier seekers and compiling more accurate tables of solar, lunar, planetary and stellar motions than were extant before his day. Having quarrelled with the next King, Christian IV, he was driven from his island and from Denmark, finding a refuge in his old age in Prague with the Emperor Rudolf, who received him with the utmost consideration, established him in the castle of Benatek and settled on him a liberal pension, which was seldom or never paid. His fame rests upon his observations and especially on the use made of them by Kepler. To the day of his death he believed that

the earth was the centre of the universe and of the orbits of the moon, sun and fixed stars, the sun being the centre of those of the five known planets. It has been remarked that "this system is in reality absolutely identical with that of Copernicus and all computations of the places of planets are the same for the two systems".

John Kepler was born and brought up in extreme poverty at Weil in Würtemberg, studied at Tübingen and became professor of astronomy at Grätz. He wrote a small book on the movements of the planets and sent a complimentary copy to Tycho Brahe, who in 1600 generously invited him to be his guest and make use of his observations. They worked harmoniously for a year, but Tycho died in 1601, imploring Kepler to finish his tables of 1,000 stars, of which 750 were completed, and to publish them under the title of the Rudolphine Tables. Kepler, on succeeding to Tycho's title and unpaid pension, found that the chief duty expected of him was to forecast the future and determine favourable aspects of the planets for the emperor, a weak and perhaps half-insane man, and to support himself by the sale of horoscopes, which he despised. He spent his time largely in completing the Tables and studying the orbit of Mars from Tycho's observations. Like all early astronomers he believed that the planets revolved in circles, because Aristotle had described the sphere as the perfect figure; and in this belief he discovered what is now known as his Second Law, that the radius vector, or line joining the centres of the sun and planet, sweeps over equal areas in equal intervals of time. Tycho's observations rendered it impossible to believe that Mars revolved in a circular orbit and after trying many oval forms in vain, he wrote in 1604 to a fellow astronomer, David Fabricius, that he had ascertained the orbit to be an ellipse, which he published to the world in his "Commentaries on the Movements of the Star Mars" in 1609, the year in which Galileo produced his first telescope. To the title he modestly added, "From the observations of the illustrious Tycho Brahe". The book contained not only his first two Laws but important truths relating to gravity and the recognition of the moon and sun as rulers of the tides. It was not till 1619 that his Third Law, that the squares of the periodic times of the planets are proportional to the cubes of their mean distances, was published in

his "Harmonices Mundi", dedicated to James I of England, of which the main theme was an elaborate system of celestial harmonies depending on the varying velocities of the planets, the spirit of the sun being the sole auditor. James replied by an invitation to visit England, conveyed by his ambassador, Sir Henry Wotton, which Kepler respectfully declined. Eleven more years of life remained to the great astronomer, spent in much poverty with constant efforts to collect his pension, always unsuccessful. The Rudolphine Tables with 1,005 stars, were finally printed in 1627 with some help from the Republic of Venice, and were for a century regarded as the supreme authority. His death occurred on his return from a fruitless visit to Ratisbon to prosecute his claims, and in the interval he had published many less important works, including a "Notice to the Curious in Things Celestial", wherein a transit of Mercury was predicted on November 7 and of Venus on December 6, 1631. The former was seen in Paris by Gassendi, being the first recorded transit, and the latter was invisible in western Europe. His immense correspondence and notes fell into the hands of some Frankfurt merchants, from whom they were purchased in 1724 by Catherine II, Empress of Russia, and edited in 1858.

THE HENBURY METEORITE CRATERS IN AUSTRALIA*

IN recent years, the discovery of circular depressions in the earth in various localities, has been of great interest to astronomers on account of the possible accumulation of further evidence for the meteoric origin of the lunar craters. A preliminary survey of such craters recently discovered in central Australia has been made by A. C. Alderman, lecturer in geology at the University of Adelaide. Their existence has long been known to local prospectors and their position is marked on the Times Atlas (London, 1922) as longitude 133 deg. 10 min. east and latitude 24 deg. 34 min. south. This is about 50 miles south of the Macdonnell Range, in the very central region of Australia. That the craters may be meteoric in origin has only been considered since 1931.

Within an area of half a square mile, at least 12 probable craters have been located, varying in size from 10 yards to 220 yards in diameter. The shattering effect in the ordinary rock formations of the country such as would be expected from a meteoric fall is evident, and a total of 1,350 pieces of meteoric iron have been found in the locality by two expeditions. These weigh anything from a fraction of an ounce to 170½ pounds.

Weathering has had its effect on the formations, and from the plains in which they are situated, the craters are not conspicuous. Standing on the rim of the largest, called the Main Crater, Alderman says the effect is startling. "A huge depression is seen, 50 to 60 feet deep and of oval shape, being about 220 yards in its longest axis and 120 in its shortest. Mulga trees and grasses cover the floor . ." Apparently vegetation of this nature has taken possession of nearly all the craters, but is most profuse in Water Crater adjoining Main Crater. Here Acacia salicina has reached a height of 45 feet, with a trunk diameter of 21 inches. The appearance of vegetation in such an arid region is due to the craters holding water after any rain.

Of most interest to astronomers will be the fact that cross-sections of the two craters mentioned resemble in no small degree lunar formations. The floor of the Main Crater is below the level of the surrounding plain, and the floor of Water Crater is at a higher level than that of Main Crater. A map showing the distribution of

*From Monthly Notes of the New Zealand Astronomical Society (April, 1934).

craters is very suggestive of the random positions of lunar craters. Of special interest are the radiations from Crater No. 3, and to which Alderman has given some attention. He says, "Radiating outwards into the plain from the crater walls, can be seen five or six low ridges of sandstone. These suggest dikes of a hard rock which has resisted erosion more successfully than the surrounding country. They consist, however, of sandstone which is apparently identical with that to be found anywhere in the neighbourhood. The "ridges" are only a few inches higher than the surrounding surface of the plain, but consisting as they do of small blocks of sandstone, of which the surface is blackened due to weathering, they are easily distinguished from the prevailing reddish colours of the surrounding boulders." In a footnote, the author reminds us of the radiations from lunar craters, particularly Copernicus.

From the nature of the vegetation, the weathering effects of the rocks and the amount of oxidation of meteoric irons, Alderman considers that the age of the craters must be reckoned in terms of thousands of years.

Comparison with the descriptions of the meteoric craters at Canyon Diablo, Arizona, and the Tunguska River in Siberia, shows that these formations are very similar. In the case of the Australian craters, however, there is a group, whereas in the other two examples there appears to be only the one large crater. This indicates that several meteors must have descended in this locality.

Much work still remains to be done on the Australian craters, especially an attempt to locate the positions of any large masses of meteoric iron. No doubt it will be interesting to have a comparison in any final surveys with the Carolina craters recently discovered in America.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Meteor Spectra—List I

The interest in meteor photography has recently increased to a considerable extent and during the last two years a number of meteor spectra have been photographed. It seems worth while to publish here a list of such photographs, as far as possible complete to the end of 1933. The writer has been especially interested in increasing the scanty amount of photographic data on this subject and a number of programmes to this end have been conducted at Harvard Observatory stations with a fair degree of success.

PHOTOGRAPHIC METEOR SPECTRA—LIST I

Spectrum	Date	Place	Identification
I.	1897, June 18	Arequipa, Peru	....
II.	1904, May 11	Moscow, Russia	....
III.	1904, Aug. 12	Moscow, Russia	Perseid
IV.	1907, Aug. 12	Moscow, Russia	Perseid
V.	1909, May 18	Arequipa, Peru	....
VI.	1920, Aug. 10	Mt. Wilson, Calif.	Perseid
VII.	1924, Mar. 7	Mt. Wilson, Calif.	....
VIII.	1924, Sept. 29	Bergedorf, Germany	....
IX.	1931, Dec. 15	Blue Hill, Mass.	....
X.	1931, Dec. 12	Blue Hill, Mass.	Geminid
XI.	1913, Jan. 9	Cambridge, Mass.	....
XII.	1932, Apr. 29	Flagstaff, Arizona	....
XIII.	1932, May 26	Flagstaff, Arizona	....
XIV.	1932, May 27	Flagstaff, Arizona	....
XV.	1932, Nov. 16, 1.00 a.m.	Oak Ridge, Mass.	Leonid
XVI.	1932, Nov. 16, 2.01 a.m.	Oak Ridge, Mass.	Leonid
XVII.	1932, Nov. 16, 2.35 a.m.	Oak Ridge, Mass.	Leonid
XVIII.	1932, Nov. 16, 3.13 a.m.	Oak Ridge, Mass.	Leonid
XIX.	1932, Nov. 16, 4.05 a.m.	Oak Ridge, Mass.	Leonid
XX.	1932, Nov. 16, 5.45 a.m.	Ft. Worth, Texas	Leonid
XXI.	1932, Nov. 17, 3.50 a.m.	Flagstaff, Arizona	Leonid
XXII.	1932, Nov. 17, 5.50 a.m.	Flagstaff, Arizona	Leonid
XXIII.	1933, Feb. 22	Flagstaff, Arizona	....
XXIV.	1933, Feb. 26	Flagstaff, Arizona	....
XXV.	1933, Apr. 21	Ft. Worth, Texas	....
XXVI.	1933, Aug. 12	Ft. Worth, Texas	....

XXVII.	1933, Nov. 15, 0.33 a.m.	Franklin, Ky.	Leonid
XXVIII.	1933, Nov. 17.	Flagstaff, Arizona	Leonid
XXIX*a*.	1933, Nov. 17, 4.48 a.m.	Blue Hill, Mass.	Leonid
XXIX*b*.	" " "	Oak Ridge, Mass.	"

The first nine spectra photographed, studied by the writer in Harvard Annals, Vol. 82, No. 6, have been included in the list. In the above publication, for convenience in reference, the meteor spectra were assigned numbers in the order in which they were obtained and it was thought preferable to extend this system of designation to those photographed in recent years.

Spectrum X and Spectrum XI are out of order. The first is a very faint spectrum, found in a second search of the 1931 meteor plates, and the second was found on an old Harvard plate by Miss L. L. Hodgdon. Numbers XII, XIII, XIV, XXIII, and XXIV were obtained on the systematic programme for meteor photography conducted by the Harvard expedition in Arizona. The plates were exposed by Dr. S. L. Boothroyd and Mr. D. J. Hargrave. Numbers XV, XVI, and XIX were photographed by Mr. Wm. Kunz, observing at the Harvard Observatory station at Oak Ridge; XVII and XVIII were obtained with observatory cameras the same night. Numbers XXI and XXII were photographed by the Harvard cameras in Arizona, the plates being exposed by Mr. K. A. Newman. The Texas Observers of Ft. Worth have secured three spectra, numbers XX, XXV, and XXVI. Spectrum XXVII was photographed by Mr. L. J. Wilson, of Franklin, Ky.

Spectrum XXVIII is very remarkable, being the first slit spectrum of a meteor. It was obtained by Dr. V. M. Slipher with a small fast slit spectrograph, an instrument usually used for photographing the night sky Dr. Slipher reported briefly upon this spectrum at the December meeting of the A.A.S. Spectrum XXIXa was obtained by Mr. E. M. Cook of the Harvard party at Blue Hill, and XXIXb refers to a very faint trace of the same meteor obtained on a red plate at the Harvard station at Oak Ridge.

To the best of the writer's knowledge the above list is complete to the end of 1933 and he would appreciate being informed of any other spectra that have been photographed. It is proposed to publish annually in these notes lists of additional spectra that may

be obtained in the future. Spectrum XXVIII is under investigation at the Lowell Observatory. The remainder are being studied by the writer and the complete report will be published in the Harvard Annals.

The Detonating Fireball of March 18, 1934

The response to requests for observations of the above meteor has been very gratifying and in the neighbourhood of 70 reports have been received, many of them of the highest quality. The complete investigation of this fireball will appear in a future number of this Journal. Several supposed fragments of this meteor have been examined, both at the University of Alberta and at Toronto, but none have proved to be meteoric in origin.

Dates for the Byrd Co-operative Programme

The dates for observing meteors in co-operation with the Byrd Antarctic Expedition (see these notes for May-June) have been slightly changed. The revised list of future dates now reads:—

July 27, 28, 29	12.00	to 4.00 a.m.
August 4, 5, 6, 7, 8, 9, 10, 11, 12	12.00	to 4.00 a.m.
October 17, 18, 19, 20	1.00 a.m.	to 4.00 a.m.
November 12, 13, 14, 15, 16, 17	1.00 a.m.	to 4.00 a.m.

The Perseids, 1934

The readers of the Journal are urged not to forget the three nights of Perseid observations, Aug. 10-11, 11-12, and 12-13, occurring at the dark of the moon. Be sure to send in any observations made, no matter how few. Plots of any meteors seen, together with accurate times, are especially desired. Of great importance is the full record of position, shape and motion of an enduring train. A network of stations is being arranged to cover southern Ontario. Maps and complete instructions may be obtained from the writer on request.

Meteor Photography by the Texas Observers

In recent years the Texas Observers of Ft. Worth have been particularly active in the field of meteor photography. During 1933 they exposed 86 plates for a total of 82.4 hours' exposure time with

chart cameras and made 56 exposures for a total of 55.5 hours with the spectrographs. Four direct meteor photographs were obtained and in two of these cases the spectra of the meteors were also secured. We are confident that the Texas Observers will be regular contributors to the accumulation of photographic data on meteors.

The Use of Photography in Recording Fireballs

A very interesting article on the fireball of March 24, 1933, by H. H. Nininger, is contained in the June-July issue of *Popular Astronomy*. It is unique in illustrating the part photography may play in the study of great fireballs, unheralded though they are. This particular object was actually photographed while in flight and the persistent train was photographed from at least four different stations. Very much more complete data could have been secured, however, had there been some organization among amateur photographers interested in using their cameras to advance science. The importance of having films always loaded in a camera and having the camera always available, cannot be over emphasized. If this rule were generally followed, far more of such impromptu photographs could be secured with but a few minutes' warning. Mr. Nininger is to be congratulated upon his recent success in locating meteorites by the investigation of observations of bright meteors. The Society for Research on Meteorites, of which Mr. Nininger is secretary, has recently been awakening people in the western states to the importance of promptly reporting all observations concerning bright meteors and suspected meteoric falls. The American Meteor Society, under Dr. C. P. Olivier, has aroused interest in meteor observing to such an extent that its annual report consists of over 60,000 observations. In recent years we have come to a greater realization of the importance of meteor observations and it is hoped that the interested amateur in Canada will not allow our Dominion to be backward in the collection of such scientific data.

P. M. M.

REVIEW OF PUBLICATIONS

Earth, Radio and the Stars, by Harlan T. Stetson. 336 pages, 5½x8 in. N.Y. and London: McGraw-Hill Book Co., 1934. Price, $3.00.

Within the last few years there have been in this JOURNAL several references to a possible connection between sunspots and radio reception, and in most cases the information given has been due to Professor H. T. Stetson. In this book three out of the twenty chapters are devoted to this subject, and the evidence in favour of such connection is convincing. Radio receives considerable attention in other parts of the book also and its relation to the moon, solar eclipses, meteors and the stars is discussed. The important observations by Jansky, from which he concluded that a high-pitched "hiss" came to his receiving antenna from a definite direction in space (corresponding to that of the centre of the Galaxy, as given by Shapley), are described; also the extraordinary echoes of radio signals noted by Hals and others, regarding which Störmer made some remarkable predictions, based on his theoretical investigations of the aurora. These investigations lead the author to remark that a new means has been found for attacking the mysteries of cosmic space, and that in the coming years radio apparatus may prove as effective a tool in astronomical research as the telescope has been in the past.

Many other recent investigations are discussed in the book. In particular, one may mention those relating to the interior of the earth, the ultra-violet radiations from the sun, cosmic clouds and cosmic rays. At the end is a valuable bibliography and a full index of names and subjects.

The book is of great interest to the astronomer as well as the educated layman. It is well written, well illustrated and well printed. Indeed this may be an appropriate place to call attention to the very creditable record of the firm of McGraw-Hill and Co., which has just completed twenty-five years of publishing useful books. C. A. C.

The Elements of Astronomy, by E. A. Fath. Third Edition, 360 pages, 6x9 in., 8 star charts, 238 illustrations. N.Y.: McGraw-Hill, 1934. Price, $3.00.

This is the third edition of Fath's well-known elementary text, revised to the end of 1933. The introductory chapters have been simplified and the later chapters have been rewritten to conform to recent researches. The present writer and his colleagues have used this book in teaching and can bear testimony to its excellence as a text. C. A. C.

Johannes Kepler, der grosse Führer und Mensch, von E. Zinner. 58 pages, 5x7½ in. Lübeck: Charles Coleman, 1934. Price, 60 pf.

This is number 41 in the series of little biographies edited by Fritz Endres and published by Charles Coleman. Dr. Zinner, the author, is director of the Remeis Observatory in Bamberg in Bavaria, and is a profound student of the history of astronomy. His studies of the life of Kepler are well known and in this little work he gives a comprehensive, though brief, account of his family and his work. C. A. C.

QUESTING

In reaches, limitless of space, confined,
The flaming worlds in rhythmic order swing,
As thrice a million stars forever cling,
To the roof of the sky their daily round assigned.
Far distant realms, born of Eternal Mind,—
Ordained when Time's first fitful pulses stirred,
Creation's dawn beheld with vision blurred,
Those worlds from Chaos merge defined.

O worlds on worlds! Our beggared phrases fail,
Man mutely stands before your regnant power,
Pursues his quest to pierce beyond the veil,
Whence is your force unseen and whence your hour?
We groping scan unanswering skies in vain,
But he who seeks will yet the answer gain.

Toronto, Ont. ANNIE MARION FOX.

NEWS AND COMMENTS

General

The new 40-inch reflecting telescope of the Naval Observatory, Washington, D.C., has been completed and is being tested. It is of the Ritchey-Chrétien type, designed to photograph a larger field than the usual paraboloid reflector.

Dr. Harlow Shapley, director of the Harvard College Observatory, delivered the George Darwin Lecture before the Royal Astronomical Society on May 11. He was presented with the gold medal of the Society.

Dr. Alfred Fowler, professor of astrophysics at the University of London, was the recipient of the Bruce medal of the Astronomical Society of the Pacific.

At the recent commencement of Queen's University, Dr. J. S. Plaskett, director of the astrophysical observatory, Victoria, received the LL.D. degree.

Columbia University conferred the doctorate of science on Dr. Ernest W. Brown, emeritus professor of mathematics at Yale University.

Dr. W. Carl Rufus and Dr. Dean B. McLaughlin have been promoted to associate professorships of astronomy at the University of Michigan.

Dr. George Cary Comstock, director emeritus of the Washburn Observatory, professor of astronomy at the University of Wisconsin and formerly dean of the Graduate School, died on May 11 in his eightieth year.

Notes from the Dominion Observatory

At the weekly meetings of the staff of the observatory during the 1933-1934 term, the following subjects or reviews of published papers were presented and discussed: Nov. 9, R. Meldrum Stewart, Dayton C. Miller's "The ether-drift experiment and the determination of the absolute motion of the earth"; Nov. 16, E. A. Hodgson, Daly's "Igneous rocks and the depths of the Earth"; Nov. 23, R. E.

DeLury, "The masses of atoms and the structure of atomic nuclei" by K. T. Bainbridge; Nov. 30, R. Glenn Madill, The Carnegie Institution's work on "Ocean magnetic observations on non-magnetic ships"; Dec. 7, Miss M. S. Burland, "The problem of classifying stellar spectra" by Otto Struve; Dec. 14, A. H. Miller, "On the measurement with gravimeters of the variation of the acceleration of gravity with time" by R. Tomaschek and W. Schaffernicht; Dec. 21, W. W. Doxsee, "The principle of the seismograph", U.S. Nat. Research Council Bull., Oct., 1933; Jan. 4, J. L. O'Connor, "Symposium on climatic cycles", U.S. Nat. Acad. Sci. Proceedings, Mar., 1933; Jan. 11, R. Meldrum Stewart, "Discovery and early history of the positive electron" by Karl K. Darrow; Jan. 18, C. C. Smith, "The test of the Wegener theory"; Jan. 25, R. E. DeLury, "Cosmic rays"; Feb. 1, J. P. Henderson, "The crystal clock"; Feb. 8, A. H. Miller, "Recent developments in gravity apparatus"; Feb. 15, E. A. Hodgson, "Geocentric co-ordinates as applied to epicentral distances" by B. Gutenberg; Feb. 22, C. A. French, "Isopors and isoporic movements" by H. W. Fisk; Mar. 1, R. J. McDiarmid, "Solar distance; transits of Mercury and Venus"; Mar. 8, Miss M. S. Burland, "The distribution of extra-galactic nebulae" by Edwin Hubble; Mar. 15, R. Meldrum Stewart, "The temperatures, linear dimensions and densities of stars"; Mar. 22, R. Glen Madill, "The origin of the aurora polaris"; Mar. 29, M. M. Thomson, "Storage batteries"; Apr. 5, E. A. Hodgson, "The idolatry of science" by Stephen Coleridge; Apr. 12, J. L. O'Connor, Carrington's "Observations of solar spots"; Apr. 19, C. C. Smith, "The third fundamental catalogue of the Berliner Jahrbuch"; Apr. 26, R. E. DeLury, "Methods of measurement of spectrum line displacements, with application to the solar rotation".

Mr. A. H. Miller departed the middle of June expecting to spend three or four months investigating with the torsion balance the salt deposits of the Malagash, N.S., region, while Dr. Walter Bell will be the representative of the Geological Survey in this co-operative work with the Dominion Observatory.

The reductions of the international longitude observations made at Ottawa and Vancouver will soon be completed for forwarding to the Bureau International de l'Heure.

Arrangements are being made for the direct comparison with the Synchronome clock of the Time Service, of the crystal clocks of the Radio Branch, Department of Marine and of the Canadian Radio Commission.

It is expected that Mr. C. A. French will occupy certain magnetic stations in continuance of the programme of repeat observations, while Mr. R. Glen Madill will make astronomical and magnetic observations during the summer in the vicinity of Hudson strait and Hudson bay. REDeL.

EVOLUTION

Up from the dust that made us;
Out of the rain and dew,
Till the first swift radiant sunbeam
Brought light and life to view.

Down through the march of ages,
While the breath of God did range
Through the heart of the pregnant atom
In the alchemy of change.

Eras and eras of planning,
Of making and moulding amain
In the simple cell and the saurian
The first faint germ of a brain;

And on through unending eons
God fashioned and framed his plan,
And clothed with the gift of reason
His image and masterpiece, man.

And out of reason a spirit,
A phoenix conceived to shine
In the light of his holy presence,
An infinite soul divine.

* * * * * *

Up from the dust that made us,
How shall we work his will,
Shall we rise to a glorious angel,
Or cling to the creature still?

Victoria, B.C. ALEX. H. SUTHERLAND.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Water-spouts in Canada

The recent request for observations of water-spouts in Canada brings forth the following report by A. G. Atkinson, Tilbury, Ont. Other reports are desired.

About thirty years ago I was out of doors one summer's afternoon, being two miles inland from the south-eastern shore of lake St. Clair. The stretch of land intervening is flat, only a few feet above the lake level, and with no trees obstructing the view.

About four o'clock I was watching a black rain-cloud which had formed in the western sky. This had rough edges, and at one place there was a dark funnel-shaped cloud hanging from it.

I recalled descriptions people had given me of tornadoes they had seen, but had no idea that such would occur here. However, while observing it, from the bottom end of the funnel a black column shot downward to the surface of the water, and I concluded I was viewing a water-spout.

As the cloud drifted towards the east the column bent at the middle until there was an angle of about forty-five degrees. And the part that went down to the water lagged behind in a perpendicular position. Eventually it parted at the bend and each part gradually disappeared.

Fishermen on lake St. Clair that day stated it looked like a column of steam rising from the lake, and they stated it was about a mile out from the mouth of the Thames river.

Coating Telescope Mirrors with Aluminum

At a recent meeting of the National Academy of Sciences, Dr. John Strong, of the California Institute of Technology, gave some account of the aluminizing process for coating telescope mirrors. The brief description which follows is taken from *Science* for May 25. It may be remarked that the Institute has generously undertaken to "aluminize" the two secondary mirrors, of diameters 18 and 20 inches, of the 74-inch reflector of the David Dunlap Observatory; and also the "pyrex" mirror and the 5-inch flat of the 19-inch reflector of the same observatory.

A steel bell jar 40 inches in diameter is evacuated by apiezon oil diffusion pumps and a Hypervac pump to 10^{-4} mm. of mercury pressure. Aluminum is distilled from twelve tungsten coils to form a uniform film 1/10 micron in thick-

ness on the surface of the telescope mirror. The mirror surface is made clean for the coating process by an electrical discharge as the bell jar is being evacuated. The evaporated aluminum coat is immune to tarnish, adheres tenaciously to the glass and is not easily scratched once the oxide film, which forms on it, is established. The reflectivity is 89 per cent. in the visible, dropping gradually to 80 per cent. at 2500 A. Measurements at Lick Observatory show the reflectivity, for photographic light exceeds silver by approximately 50 per cent. Stellar spectra to 3000 A have been obtained.

Books Added to the Library

The Assistant Librarian reports that the following books have recently been added to the Society's library:

Colgrove, W. G., A Ready Reference Handbook to the Solar System.
Eddington, Sir Arthur, The Expanding Universe.
Ellison, W. F. A., An Amateur's Telescope.
Forbes, George, The Earth, the Sun and the Moon.
Jeans, Sir James, The Background of Science.
Frost, Edwin B., An Astronomer's Life.
Joad, C. E. M., Guide to Modern Thought.
Macpherson, Hector, Makers of Astronomy.

C. A. C.

MEETINGS OF THE SOCIETY

AT TORONTO

March 27, 1934.—The meeting was held at the usual time and place. Mr. A. R. Hassard was in the chair.

Mr. J. R. Collins reported the recent announcement from the Harvard College Observatory of corrections to the orbit of the eighth satellite of Jupiter and of the discovery of an asteroid of the eighteenth magnitude. Mr. R. S. Peterson, 99 Spencer Avenue, Toronto, was elected a member (Toronto Centre) Mr. George C. Van Dusen, 1461 Northwestern Bank Bldge., Minneapolis, Minn., was nominated for life membership.

The predictions of phenomena for the next two weeks were given by Mr. F. L. Troyer. These were supplemented by remarks by Mr. Hassard on the phenomena of Jupiter's satellites and other phenomena occurring later in the year.

The explanation of "wet" and "dry" moons was given by Mr. Hassard, although there is no scientific basis for this form of weather forecasting. Mr. Hassard mentioned the coincidence that the recent weather in Toronto seemed to support it. Mr. Hassard reported that no sun spots were visible on the solar disc when observed in a seven-inch reflector, using a magnification of 150. Mr H. G. Duncalfe mentioned the existence earlier in the evening of a lunar halo in which the colours were quite prominent. A strong auroral display was observed on March 14 from midnight until 2 a.m.

The address of the evening was given by Mr. J. R. Collins, in the form of a review of Jeans' recent book, "The New Background of Science", which is supplementary to his "Mysterious Universe". Although Sir James Jeans is one of the leaders in the popular exposition of the physical sciences and astronomy; to review this book thoroughly in a short time is rather difficult, owing to the metaphysical viewpoint from which it is written. The development of scientific thought from the time of Aristotle, who considered matter to be continuous, through the stage when the atom of an element was thought to be the ultimate unit, to the present conception of electrons, protons and photons is explained. Until recently, too, it was a fundamental concept that a certain cause always produced a certain result, this being the principle of determinacy. So long as matter is studied in bulk, with a large number of units taking part, there are no exceptions to this; but, as the study of the structure of the atom progressed to the stage where relatively few units entered into a reaction, it was found that the principle of determinacy was inadequate to explain some of the results obtained. This has resulted in the formulation of a principle of indeterminacy, based on probability rather than certainty. At present there are two main outlooks on science, that of the realist or materialist, the so-called "common sense" view, and that of the idealist or mentalist. The present trend is toward the latter

viewpoint, for the universe is explained most readily in the language of the mentalist, and there are no signs indicating a change to the other viewpoint at present. No one knows, however, what may await us around the next corner and cause a revision of our ideas once again.

A very interesting demonstration of the "Twin Elliptical Pendulum" was given by its maker, Mr. H. G. Duncalfe. The instrument consists of two pendulums, each mounted on gimbals to permit of motion in any direction. The upper pendulum carries at the bottom a small horizontal table to support a sheet of paper upon which a stationary pen rests. The second pendulum swings from a mounting attached to the lower side of this table. Each pendulum is set in elliptical motion, after which the pen is lowered on to the paper. The resulting motion of the paper beneath the pen is a composite of the elliptical motions of the two pendulums, and by properly choosing the weights for each pendulum very intricate and beautiful designs are traced.

April 10, 1934.—The meeting was held in the auditorium of the McLennan Laboratory, University of Toronto at 8 p.m. The meeting was called to order by the Vice-Chairman, Mr. A. R. Hassard, who on behalf of the Society, welcomed the large number of guests who were present, the audience numbering over two hundred.

Mr. George G. Van Dusen, 1461 Northwestern Bank Building, Minneapolis, Minn., was elected a life member of the Society.

Mr. Hassard reported that observations of the sun, made with his seven-inch reflector, throughout the previous two weeks, had shown the sun to be free from sunspots during that period. He also referred to the relation between the aurora and spottedness of the sun.

The main item on the programme was a series of science motion pictures of a popular nature, arranged by Mr. F. L. Troyer. The first picture, a two-reel film entitled "The Benefactor", dealt with the life of Thomas A. Edison from boyhood to manhood and with the part played by his creative genius in making life easier and happier for all mankind.

"Beyond the Microscope" was the title of the next film. This had to do with things too small to be seen in the most powerful microscopes—the molecule and the atom. By means of animated diagrams the structure of the atoms of hydrogen and oxygen were shown, as well as the manner in which two hydrogen atoms combine with one of oxygen to form a water molecule. The process of the electrolysis of water, and the manner in which ice and snow crystals form were also clearly explained. This film and the previous one were shown through the courtesy of the Canadian General Electric Company. "Communing with the Heavens" is the title of a very fine picture, obtained from the Dominion Government, which is almost the equivalent of a trip through the Dominion Observatory at Ottawa. In it the operation of the various instruments at this observatory is shown and clearly explained. The final film, "The Romance of the Skies", showed the structure of the solar system and the motions of the earth, the moon and the planets, and also dealt with comets and solar eclipses. Although it was possible to find features in this picture to which objection might be taken, the picture taken on the whole was quite good.

Previous to the showing of each film a brief explanation of what was to be shown was given by Mr. Troyer, which added much to the enjoyment of the pictures. Mr. Troyer is to be complimented on the success of the interesting and instructive programme which he provided. After expression of thanks to the Dominion Government, to the Canadian General Electric Company (who were kind enough to provide a projector, as well as three reels of films), to Mr. Troyer who arranged the programme, and to the operators of the projectors, Mr. K. O. Wright and the Recorder, the meeting was adjourned.

H. F. BALMER, *Recorder.*

April 24, 1934.—The meeting was held at the usual place. In the absence from the city of the chairman, Mr. A. R. Hassard, K.C., took the chair and called the meeting to order at 8.00 p.m.

Predictions of astronomical phenomena for the following two weeks were presented by F. L. Troyer; and a number of recent observations were reported by Mr. Hassard and others. While the matter of phenomena was under consideration, Dr. Chant mentioned that he had recently received a letter drawing his attention to a supposed error in the OBSERVER'S HANDBOOK. The letter stated that the observed positions of Jupiter's satellites on the evening in question were not as shown in the book. Dr. Chant pointed out that a definite time is shown at the top of the column, for which date and time the satellites will be located as shown. However, when this given time is after midnight, the observer when making evening observations should refer to the entry for the following date.

Mr. K. O. Wright conducted the ten-minute constellation study, the group under consideration being Virgo.

Dr. C. A. Chant then addressed the meeting on, "Are the Stars Infinite in Number?" It was remarked that many persons looking up at the sky on a clear night express their astonishment at the "numberless" stars, but in the entire celestial sphere there are less than six thousand stars bright enough to be seen by the unaided eye; and as any observer can see only the stars in one hemisphere at a time, and the fainter stars near the horizon are usually invisible because of haze or buildings, the total number of stars visible at any time without optical aid is about two thousand, or at most, twenty-five hundred.

Using lantern slides and blackboard diagrams to illustrate his remarks, Dr. Chant explained how better optical instruments and longer exposure of photographic plates were of value to the astronomer in estimating the number of stars in our sidereal system.

Taking a few individual stars they may differ greatly, but on the whole the stars are all very similar to one another, and we may assume that throughout our entire galaxy they are of about the same absolute brightness. Their apparent brightnesses, from which their "magnitudes" are calculated, serve as indicators of their distances. Also, we may assume that the stars are fairly evenly distributed throughout the galaxy, the total number of stars should be proportional to the space considered, from which it follows that each succeeding

magnitude limit should contain about four times as many stars as in all previous magnitudes.

Actual observation, however, shows that this ratio falls off rapidly with the fainter stars. Since, when we go farther into the outer regions of our galaxy the number of stars per unit of volume decreases, at last we must come to the limits of our stellar system. The number of stars is therefore finite,—possibly of the order of thirty thousand million stars, a very great number, but still not infinite. But this vast sidereal system, or galaxy, of ours is not the only "universe" in existence. Beyond all this there are probably a million or more other galaxies, similar in most respects to our own.

FRED. L. TROYER, *Acting Recorder.*

AT LONDON

March 9, 1934.—The meeting was held in the London Life Building, Mr. Geo. Gunn, the president, in the chair.

The president read a few interesting paragraphs from Sir James Jeans' book, "The Stars in their Courses."

Mr. F. H. Coates demonstrated the use and operation of a seismograph. The model he used consisted of an upright shaft which when in use would be firmly fastened to a rock foundation. To this was attached a horizontal arm which swayed freely from side to side and at the end of which was a recording pen. This pen made ordinarily a straight line along a strip of paper constantly unrolling under it, but when a shock occurred the line became zig-zag, the curves being deeper as the shock was greater. This type of instrument would record shocks coming only from the left or right, but the speaker described others that would record earth disturbances coming from any direction.

Major E. H. Anundson introduced his address on the sun in a graphic way by showing that a motor car running 93 miles per hour day and night would take a long lifetime of nearly 114 years to cover the distance from us to the sun. A photograph was projected on the screen, showing the darkened appearance towards the limb of the sun. This is explained by the rays from this part coming to us slantingly through the solar atmosphere, while those from the centre of the disk come more directly.

A series of photographs of prominences was shown, exhibiting the speed with which these outbursts of flaming matter are shot from the chromosphere. These when seen against the sun appear as bright clouds. Other series showed the movement of spots across the sun's disk by means of which the time of rotation is calculated to be about 25 days at the equator and 30 days towards the poles. Some of the interesting discoveries of the composition of the prominences and the corona made by means of the spectroscope were recounted.

April 13, 1934.—The meeting was held in the same place, Mr. Gunn presiding. The attendance was 35.

Mr. F. H. Coates was the speaker of the evening, having for his subject, "The Great Pyramid of Gizeh—Man's Earliest Observatory." Having spoken on this subject two years previously, the speaker dealt less with the mathematical features of the pyramid and gave more description of the monuments raised by

the ancient civilizations around the Mediterranean Sea and the reasons for believing them to have an astronomical signification.

Of Egypt itself, the speaker deplored the fact that so much of the ancient writing was destroyed by the numerous invasions that country suffered. But sufficient remains to show that the Great Pyramid was designed for astronomical uses. Like many other pyramids in Egypt, this one was built with sides facing the cardinal points. It is believed from records found, that tablets once marked the length of the noon shadow made by the pyramid at the summer solstice as well as the reflection of the sun from its slightly curved side and that these tablets bore hieroglyphics telling their purpose. On the northern face at the 35th course or step of this great structure there is a square entrance to a tunnel which descends below the surface of the rock on which the pyramid is built. From the lower end of this tunnel could be seen Alpha Draconis, the pole star at the period in which the pyramid was built—about 2700 B.C. Records found in the pyramid show that the ancient Egyptians had some knowledge of the rotation of the earth as we think of it to-day.

The speaker showed the difficulties the architects had to overcome in the erection of this huge structure containing 2½ million blocks of stone and covering 13 acres of ground. The almost perfectly square base and the exactness with which the casing stones were cut and fitted were emphasized. The lecture was illustrated by pictures taken by the speaker himself during a visit to the Mediterranean and Egypt in 1919. N. MORRIS, *Secretary-Treasurer.*

AT MONTREAL—SEASON 1933-34

November 2, 1933.—The first meeting was held in the Macdonald Physics Laboratory at 8.30 p.m.

The annual business meeting was first held with report of Secretary and Treasurer, and election of officers.

Officers, 1933-34

Honorary President—Mgr. C. P. Choquette.
President—Mr. Geo. Harper Hall.
1st Vice-President—Dr. D. A. Murray.
2nd Vice-President—Dr. Julian C. Smith.
Secretary-Treasurer—Dr. A. Vibert Douglas.
Council—Dr. A. S. Eve, Dr. L. V. King, Mr. Justice E. E. Howard, Lt.-Col. W. E. Lyman, Dr. A. H. McCordick, Prof. N. B. MacLean, Mr. O. A. Ferrier, Dr. W. D. Lighthall.

New members elected were: Mr. Frank Bailey, Mr. C. D. Rutherford, Mrs. W. H. Spencer, Mr. Dan P. Gilmore, Miss M. F. Hadrill.

The lecturer was Dr. A. Vibert Douglas, the subject being "Novae—Nature's Greatest Cataclysms." The history of Novae was given and illustrations were shown of the light changes and particularly the spectroscopic evidence and its interpretation. Imagination is taxed to the utmost to comprehend the vastness of this greatest known cataclysm of nature, and scientific skill is seen in the interpretation of the starlight message—ancient history imprinted within ripples of radiant energy.

November 16, 1933.—The second meeting was held in the same place with the McGill Chapter of Society of Sigma Xi,

December 6, 1933.—The third meeting was held in the same place, at 8.30 p.m., the president, Mr. G. Harper Hall, in the chair.

New members elected: Mr. Henry F. Hall, Mr. Maurice Oulimar.

The Secretary read the following resolution and a standing vote was taken:

"Inasmuch as the Montreal Centre of the R.A.S.C. has from its inception been closely identified with McGill University, in whose buildings its first meeting and the majority of its subsequent meetings have been held, it therefore desires to record its profound sense of loss in the removal by death of Sir Arthur Currie, Principal of McGill University, and to express its deep sympathy with Lady Currie and her family."

The lecturer was Dr. W. H. Watson, Assistant Professor of Physics at McGill University. The subject was "The Electrical Properties of Light."

He first quoted Mach that a knowledge of the history of science is necessary to an understanding of science; then proceeded to discuss the work of Faraday—102 years since he discovered electro-magnetic induction, and the "Faraday effect"—of the turning of the plane of polarization in a magnetic field. This was demonstrated by means of an electromagnet having nicol prisms in the pole pieces. In 1857, Clerk Maxwell threw light on this phenomenon by his dynamical theory of the electromagnetic field. Reference was made to the contribution of Hertz in 1887 extending the range of known electromagnetic radiations. An experiment was shown to illustrate the ionizing power of light and the photo-electric properties. Two spark gaps were arranged and the spark passed chiefly at one, but when light from a carbon arc played on the other (a brass-zinc gap) the spark passed more freely across it. In 1888, Hallwachs investigated this photoelectric property of zinc as a negative electrode. Briefly the new knowledge opened up by the study of X-rays, radioactivity, and the electron was outlined and considerable attention was given to photoelectric cells. In conclusion, the great contributions of Einstein and Planck were discussed, and the revolution of thought regarding the nature of light.

At the request of Mr. Justice E. E. Howard, the lecturer explained the opening of the Chicago Exposition by the trigger action of the current generated by the light of Arcturus concentrated by the Yerkes 40-inch telescope upon a photo-electric cell.

January 19, 1934.—The fourth meeting was held in the same place, at 8.30 p.m., the president occupied the chair.

New members were elected as follows: Miss Elizabeth Robertson, Mr. Frank DeKinder.

The speaker was the vice-president, Mr. Julian C. Smith, LL.D., and his subject was "The Mount Wilson Observatory." The speaker described a visit to California and Arizona made just at the time of the earthquake of March 10, 1933. Slides were shown of the Mt. Wilson equipment and the various instruments were described and reference made to the lines of astronomical and astrophysical research carried on there. Reference was also made to the 200-inch telescope

now under construction, to the solar furnace in Pasadena, and to the great meteor crater in Arizona.

January 29, 1934.—The fifth meeting was held jointly with the McGill Physical Society in the Physics Laboratory at 5 p.m,

The speaker was the Abbé Georges Lemaître, who was again passing through Montreal and who spoke on Cosmic Rays, the recent observational data and the mathematical attack on the problem of the influence of the earth's magnetic field upon a shower of charged particles—probably positive particles coming in from outer space. This mathematical investigation has been taken up by Lemaître and Valarta (M.I.T., Cambridge, Mass.).

February 9, 1934.—The sixth meeting was held, by the courtesy of the Engineering Institute of Canada, in the Windsor Hotel at 9.30 a.m. on Friday, February 9th—a regular session of the Annual Meeting of the E.I.C., at which Dr. R. K. Young of the University of Toronto was presenting a paper upon the engineering features of the David Dunlap telescope of the University of Toronto. This lecture was illustrated by excellent slides showing the various parts of the mounting and controls, the mirror disc, the dome, etc.

March 15, 1934.—The seventh meeting was held, at 8.30 p.m., in Macdonald Physics Laboratory. The president was in the chair.

There were three addresses given by members of the Montreal Centre and illustrated with lantern slides and charts.

(1) Mr. Henry F. Hall discussed the sun as centre of the solar system, its physical characteristics and its position among the stars.

(2) Mr. DeKinder spoke about the planets, giving a résumé of present-day knowledge with regard to their natures, their satellite families and so forth.

(3) Mr. E. Russell Paterson reviewed the facts and speculations regarding the moon, its physical condition, origin, etc.

Many questions were asked, and the president drew the attention of members to the book, "The Solar System, 1,000 Facts," by Mr. W. G. Colgrove, London, Ont.

April 19, 1934.—The eighth meeting was held in the same place, at 8.30 p.m.

New members were elected as follows: Prof. Alfred Stansfield, Mrs. W. J. Armstrong, Mrs. F. M. Lawrence, Mr. Robert Hetrick, Mr. H. MacNeil, Mr. W. A. Higgins, Mr. Francis P. Morgan.

A resolution was passed unanimously to the effect that a note be sent to Mr. Justice E. E. Howard, regretting his enforced absence from the meetings through ill-health, and expressing the high esteem in which he is held by the members of the Society, who know of his many years of interest and service in its behalf.

A lecture was delivered by the Secretary on the subject: "Telescopes great and small." The history of the early development of telescopes was given, with quotations from Galileo's account of his early efforts and discoveries. Experiments were shown illustrating the focussing of a beam of light by means of lenses, both for visual and for photographic work. Focussing by means of mirrors was also illustrated, and the elementary facts of spectrography were described, and emission and absorption spectra produced. Slides were shown of some of the great modern telescopes in Europe and on this continent.

A. VIBERT DOUGLAS, *Secretary.*

The Royal Astronomical Society of Canada

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Recorder—H. F. Balmer, M.A.
Assistant Curator—F. L. Troyer
Observation Committee—Dr. C. A. Chant; A. R. Hassard, K.C.; J. R. Collins; Dr. P. M. Millman; J. H. Mallory.

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